ИЗВЕСТИЯ
АКАДЕМИИ НАУК СССР
СЕРИЯ ГЕОЛОГИЧЕСКАЯ

IZVESTIYA AKAD. NAUK SSSR

SERIYA GEOLOGICHESKAYA

1959 CONTENTS No. 8, August

T-08905. Approved for printing July 18, 1959.
Circulation - 3850 copies. Order 3538.
Paper size 70 x 108-1/16. Paper 4. Printing sheets 10.96 + 1 ins. Publ. sheets 12.3

Second printing office of the USSR Academy of Sciences Publishing House.
Moscow, Shubinskiy per. 10.

THE DEVELOPMENT OF MAGMATISM IN BULGARIA AND THE DISTRIBUTION OF THE ASSOCIATED ORE DEPOSITS[1]

by

Str. Dimitrov

The territory of the Bulgarian People's Republic, located in the central part of the Balkan Peninsula, has an extremely complex geologic structure resulting from a violent geologic past in which magmatism played a very important role.

The study of the development of magmatism and its relation to tectonics and ore deposition in Bulgaria was initiated on the basis of a broad generalization petrographic investigations published by me in 1939. In the following year, Stille [17] made a more detailed theoretical analysis of the tectono-magmatic relationships in the geologic structure of Bulgaria, based on his concept of the so-called "normal course" of development of tectonics and magmatism in geosynclinal belts. He separated the following main stages: 1) the geosynclinal regime with initial simatic magmatism, 2) the orogeny with sialic "lithogenic" plutonism, 3) the quasi-cratonic condition with subsequent sialic volcanism and 4) the completely rigid (platform) condition with simatic volcanism. An attempt to apply this scheme to the development of magmatism and tectonics in Bulgaria showed that it can be done in a general way only if the details of geologic structure are disregarded.

The general picture of the distribution and sequence of the formation of magmatic complexes and their relation to tectonics was subsequently augmented and revised by me on the basis of now geological data [6, 10]. At the same time, V.E. Petraschek [12-15] applied himself to the problems of metallogeny and its relation to magmatism and tectonics within the broader framework of the Alpine orogeny of southeastern Europe. These problems were also studied in a general way by Iv. Kostov [11]. In recent years the problems of magmatism and endogenic ore formation have been paid particular attention in the Soviet Union, and this gives me an opportunity to present a brief summary of the present state of our knowledge of the development and relationship between magmatism, tectonics and ore formation in the territory of Bulgaria. I shall try to apply the scheme proposed by Yu. A. Bilibin and the collective of the geologists of the VSEGEI (1955) in order to see how well our concrete example fits it.

The history of the tectono-magmatic development of Bulgaria embraces three long cycles: 1) the pre-Silurian (Precambrian-Cambrian?), 2) the Paleozoic-Variscan, and 3) the Alpine.

MAGMATIC COMPLEXES AND MINERALIZATION IN THE ANCIENT CRYSTALLINE BASEMENT (PRECAMBRIAN-CAMBRIAN ?)

The ancient crystalline basement occupies the larger part of the southern half of the country. It is exposed mainly in the Rhodope massif and in the central part of the Srednegor'ye (Fig. 1). Two series of schists are distinguished in it, the lower, strongly metamorphosed series with widely developed migmatization and granitization and the upper, less strongly metamorphosed series, predominantly of the epizone facies. The crystalline basement contains large masses of granites and granite gneisses. The widespread amphibolites, hornblende schists and leptites of the lower metamorphic series may with some certainty be regarded as metamorphosed representatives of the oldest geosynclinal volcanics.

The lower series contains large bodies of granite gneisses which many investigators regard correctly as migmatites, although it is not impossible that some of them are true orthogneisses formed from the ancient abyssal granitic intrusions. Unquestionably magmatic are the numerous small basic and ultrabasic plutons scattered throughout the crystalline basement and metamorphosed into

[1] O razvitii magmatizma i razmeshchenii suyazannykh s nim rednykh mestorozhdeniy bolgarii.

orthoamphibolites and serpentinites, respectively. The so-called "Struma diorite formation," until recently referred to the Paleozoic, should be grouped with these plutons.

The same may be said of the serpentinites, for, like the diorites, they are cut by granite pegmatites and therefore cannot be younger than the parent granite. The age of the granite, according to the latest date from investigations in southwestern Bulgaria, must be considered pre-Silurian, for Silurian strata are not metamorphosed at the contacts with the granites of the South Bulgarian type. This is in essential agreement with the results of experiments in the determination of absolute age of some of the granites and pegmatites by the lead method on allanites. The maximum ages obtained are from 350 to 400 million years[2] and suggest probable Caledonian age for the granites.

The granites of the ancient crystalline basement are of the South Bulgarian type and occur as large batholiths in the cores of the dome-like brachyanticlines or cut through the metamorphic complexes. They are bordered by feldspathization aureoles traversed by numerous pegmatites.

The magmatism of the Precambrian-Cambrian cycle apparently ended with the intrusion of dike rocks ranging in composition from diorite to granite porphyries with the latter predominating. There are other granitoids in the crystalline basement, but their age relationships have not been established.

The ancient crystalline basement is poor in ore deposits: Small late magmatic chromite deposits are genetically related to the ultrabasic intrusions mainly in the southern part of the Rhodope massif, and a very few contact metamorphic magnetite deposits of the skarn type are associated with the large granitic intrusions. Some of the granite pegmatites contain beryl.

On the basis of the established relative age of the magmatic complexes of the ancient crystalline basement, and on the assumption that they all belong to the same pre-Silurian geosynclinal cycle, the sequence of formation of the individual magmatic complexes agrees well with the existing schemes of magmatic development in geosynclinal zones. The initial stage is represented by the geosynclinal, mainly basic volcanic rocks and their tuffs; the early stage is marked by the emplacement of basic and ultrabasic plutonites; the middle or batholithic stage, by the formation of large granitic bodies with associated intensive migmatization; and to the last stage; corresponding to his stage of subsequent volcanism, Stille refers the dike rocks.

[2]Unpublished data of N. Yordanov, Assistant at the Department of Analytical Chemistry, Sofiya State University.

THE DEVELOPMENT OF MAGMATISM AND ORE DEPOSITION DURING THE VARISCAN CYCLE

We have rather complete data on the ages of the igenous rocks related to the Variscan tectonic activity which occur in the Paleozoic core of Staraya Planina and in southwestern Bulgaria. The initial stage of magmatism in this cycle was marked by large geosynclinal eruptions which extruded vast masses of spillites and basalts. They are sometimes accompanied by quartz keratophyres, tuffs and tuffaceous sediments of the so-called basalt-phyllite formation, which is undoubtedly lower Paleozoic, and on the basis of lithological analogy is considered Devonian.

Before the Upper Carboniferous, the Variscan geosyncline was subjected to intensive folding (Sudeten phase of folding?). This disturbance was accompanied by the emplacement of a number of plutons, mainly stocks and relatively small batholiths, known as the calcalkalic intrusive formation of Staraya Planina. Here the succession of intrusions included gabbros, diorites, granodiorites and, finally, rather small plutons of amphibole-biotite and pegmatoidal granites. The intrusion of these granites was probably coincident with the culmination of folding (they often have flow structure), and intrusion of the pegmatoidal ("Klisurskiy") granite was accompanied by intensive migmatization of the invaded basalt-phyllite formation. These intrusions produced numerous comagmatic aschistic dikes of diabase, diorite, granodiorite and granite porphyries.

In the Silurian-Upper Carboniferous interval, and perhaps a little later, during the entire period of consolidation of the folded zone, a number of small intrusives of the Mediterranean alkalic magma type were emplaced in Staraya Planina, including potassic alkalic quartz syenites, shonkinites, tinguaites, bostonites and other rare igneous rocks.

The magmatic activity of the Variscan cycle terminated in minor extrusions of rhyolites during the Permian and in the formation of small, mainly vein-like bodies of potassic and sodic alkalic syenite porphyries, which often cut the lower beds of the redbed series. These igneous rocks were products of the final stage of variscan magmatism.

Paralleling this "normal" development of magmatism, there occurred the deposition of endogenic ores. Minor mineralization in volcanic and sedimentary rocks and hydrothermal veins is related to the initial stage of magmatism represented by the basalt-phyllite formation. The contact metasomatic mineralization in marble and the hydrothermal deposits of iron, copper and lead-zinc ores with tungsten,

FIGURE 1. Magmatic and metamorphic complexes and the most important metallic ore deposits of Bulgaria.

1 to 4, ancient crystalline basement (Precambrian): 1 -- schists; 2 -- South Bulgarian granites; 3 -- migmatic granite gneisses; 4 -- amphibolitized diorites, "Struma diorite formation" (a), serpentinites (s); 5 and 6, Hercynian magmatites and metamorphics: 5 -- basaltphyllite formation; 6 -- Staraya Planina potassic-alkalic plutonites (a), comagmatic dike formation on Staraya Planina (b); 7 -- Jurassic metamorphics (southeastern Bulgaria) with leucocratic granite intrusions (l); 8 and 9, magmatites of the Srednegor'ye structural belt: 8 -- Upper Cretaceous volcanics of Srednegor'ye - sub-Balkan volcanic belt; 9 -- "Laramide intrusives: of Srednegor'ye; 10 -- Tertiary volcanics of the Macedon-Rhodope region, Neogene basalts (B).

Symbols in the legend indicate the most important mineralizations related to definite magmatic complexes.

silver, arsenic and other metals are related to the intrusions in Staraya Planina. The alkalic plutonites of the latest stage contain a high concentration of rare earths — lanthanum, cerium, yttrium, scandium — and have caused varied and valuable mineralization.

THE TECTONO-MAGMATIC RELATIONS AND ENDOGENIC MINERALIZATION OF THE ALPINE CYCLE

The first manifestations of the Mesozoic magmatic activity were discovered recently in the form of basic flows and tuffs in the Liassic and Tithonian of southeastern Bulgaria (Sakar Planina and Strandzha Planina). Besides these products of basic geosynclinal volcanism, in the middle Liassic and in the Oxfordian-Kimmeridgian there occurred tabular intrusions of peculiar leucocratic granites and granite porphyries resembling microcline and albite alaskites, which, as is known, are not quite usual for this stage of development of magmatic activity (G. D. Afanas'yev [2]). By analogy with quartz keratophyres and albitophyres, these rocks might be regarded as the products of evolution of simatic magma, but it is difficult to reconcile this interpretation with the large size of the leucocratic granite bodies and the relatively limited distribution of Jurassic basaltic flows.

Between the Jurassic and Upper Cretaceous, but most likely immediately after the Jurassic, at the time of early Kimmeridgian folding, the Jurassic geosynclinal granites were subjected to regional metamorphism quite similar to the regional kinetic metamorphism of the Jurassic sediments in the western Alps. Evidently this metamorphism had no connection with intrusive activity. The geological data indicate that this regional metamorphism was induced mainly by intensive stresses. Insofar as it is impossible to prove theoretically the mechanical origin of the heat energy required for metamorphism, it must be assumed that stresses aided the flow of ascending hydrothermal solutions and thus had an indirect effect on the rise of temperature in the region undergoing metamorphism.

In the Cretaceous period the region of magmatic activity was shifted northward together with the geosyncline. Very probably this was the time of emplacement of several small diorite intrusives and diorite porphyry dikes which cut the Jurassic and Neocomian strata of Staraya Planina in the vicinity of the towns of Botevgrad and Etropole. There are reasons to believe that the polymetallic deposits in the Middle Triassic rocks near the Iskür River canyon are related to these very poorly exposed intrusives. V. E. Petraschek [12] ascribes these intrusives to the Upper Cretaceous volcanism in the Srednegor'e belt, the so-called sub-Balkan volcanic belt. It should be noted, however, that these intrusives are spatially isolated and on the basis of geological evidence may be considered as independent Middle Cretaceous intrusives.

The Srednegor'ye orthogeosyncline was formed during the Upper Cretaceous and filled with great masses of andesites, latites, tuffs and tuffaceous sediments. According to Stille [17], the composition of the products of this volcanic activity, although it was localized in the orthogeosyncline, indicates not the initial simatic volcanism but subsequent sialic volcanism. The latter, in Stille's opinion, has its source in "lithogenic" magma formed in the lithosphere during the preceding phase of intensive folding. Since this phase was not manifested in the region, Stille resorts to the hypothesis of "allochthonous" and "parachthonous" magmas formed elsewhere, either in distant or in neighboring regions, and in our case in the Vardar River zone or in the Rhodope massif during the supposed Austrian tectogenesis. Later, in the Senonian, this magma moved subcrustally to the Srednegor'ye geosyncline. Petraschek holds the same view and applies it to the above mentioned polymetallic deposits near the Iskür River canyon in Staraya Planina.

Genetically related to subaqueous volcanism in the Srednegor'ye zone are several rather large manganese deposits and many small copper mineralizations of the volcanic sublimate type containing native copper, copper sulfides and hematite associated with zeolites, prehnite and epidote. At the end of the Upper Cretaceous, the subsqueous volcanism in the region of Panagyuriashte culminated in the eruption of sub-extrusive and extrusive dacites and the formation of extensive propylitized zones containing copper and pyrite deposits of the Bor and Majdanpek type of eastern Siberia.

Between the Upper Cretaceous and pre-Obonian, at the beginning of the Tertiary period, the Srednegor'ye geosyncline was subjected to intensive folding, and near its southern border a number of hypabyssal, predominantly fissure plutons were emplaced, small but varied in composition and structurally complex. They are characterized by mixed chemical composition (Pacific and Mediterranean). The succession of intrusives in this area includes pyroxenite, gabbro, diorite, monzonite, syenite and granite, and in eastern Bulgaria, a series of comagmatic dikes. In the Srednegor'ye belt, young magmatism produced a number of contact metasomatic deposits and hydrothermal veins carrying mainly iron and copper but sometimes also tungsten, molybdenum and other metals.

In the Eocene the magmatic activity spread

An Outline of Development of Magmatism, Tectonics and Endogenic Ore Deposition in Bulgaria

Main stages of formation of folded regions (after Yu. A. Bilibin, VSEGEI)	Ancient crystalline basement (Precambrian — Cambrian ?)	Hercynian foundation of Staraya Planina and southwestern Bulgaria	Alpine tectono-magmatic cycle
Initial stages	? Orthoamphibolites and lepite orthogneisses in the middle of the lower metamorphic series	Diabase-quartz keratophyre (diabase phyllite) formation — Devonian ?; X, Fe	A. Southeastern Bulgaria — Strandzha and Sakar. Diabases and tuffs in the Lias. Leucocratic granites and trachytes; X, Fe Diabases and tuffs in the Tithonian
Early stages	First regional metamorphism and formation of magmatic granite gneisses Amphibolitized diorites and serpentinized ultrabasic plutons in both metamorphic series; X, Cu	Staraya Planina calc-alkalic intrusives: Hypabyssal basic intrusives—gabbro and norite; Cu	Kinetic regional metamorphism — early Kimmeridgian folding B. Staraya Planina, vicinity of Botevgrad and Etropole — Middle Cretaceous (?) dioritic hypabyssal intrusives; ? X, Pb, Zn, Cu, (Co, Ni) C. Srednegor'ye geosyncline. Sub-Balkan Upper Cretaceous volcanic belt: andesites, latites, tuffs and tuffaceous sediments; X, Mn, Cu, dacites propylitization with pyrite, Cu
Middle stages	Granite batholiths of the South Bulgarian type. X, Fe; Be in pegmatites	Sudeten phase of folding and successive intrusion of diorite, granodiorite, amphibole-biotite granite ("Mezdreisk" type) and pegmatoidal granites of the Klisurskiy type; X, Fe, Cu, Pb, Zn, W, Mo, As	Laramide-Srednegor'ye phase of folding with synchronous formation of complex plutons: Laramide intrusives: gabbro, and gabbro-diorites, monzonites, monzonite-syenites and granites; X, Fe, Cu, (Mo, W)
Late stages	Comagmatic dike rocks, most frequently granite porphyries	Comagmatic dike formation diabase to granite porphyries Pre-Upper Carboniferous (?) potassium alkalic syenites in Staraya Planina; X, Rare Earths, Cu, Sb Saalian phase of folding Permian rhyolites	Comagmatic dike formation of southeastern Bulgaria: gabbro porphyries, monzonite porphyries, syenite porphyries. D. Rhodope massif: Paleogene volcanics: andesites, dacites, rhyolites, tuffs, tuffaceous sediments Savoyian phase of folding. Early Tertiary intrusives in eastern and central parts of Rhodope massif, most often monzonites; X, Pb, Zn, (Cu, Sb) A few volcanos with trachyandesitic lava in the Struma valley, southwestern Bulgaria
Final stages	?	Alkalic dikes in the Lower Triassic of southwestern Bulgaria	Basalts

to the south into the Rhodope region, which began gradually to subside. The deep fractures which developed here caused intensive volcanic activity responsible for the vast masses of andesites, dacites, rhyolites, tuffs tuffaceous sediments. Volcanism reached its culmination in the Oligocene. It was followed by the formation of hypabyssal and subextrusive bodies represented by small stocks and dikes of monzonite porphyry and related rocks intruded into the Paleogene volcanic and sedimentary complexes or into the ancient crystalline basement of the central and eastern parts of the Rhodope massif. Genetically related to this magmatism in the Rhodope region are rich polymetallic veins and metasomatic deposits, partly of the skarn type.

Magmatic activity subsided rapidly towards the end of Alpine time. In southwestern Bulgaria along the Struma River valley, a few volcanoes remained active during the Neogene, and erupted trachyandesites. It is probable that the numerous but small basaltic flows along the east-west faults traversing northern Bulgaria, Staraya Planina and Srednegor'ye were extruded at this time.

SUMMARY

Bilibin's scheme, like those previously proposed, aids in making comparative studies of the development of magmatism, tectonics and metallogeny in the different mobile zones and different tectonomagmatic cycles. Such studies reveal general regularities and specific peculiarities which, to a greater or less degree, disturb the normal course of related processes.

As emphasized by Stille, the variations in the normal course of development arise, first of all, because during a geotectonic cycle a given phase of folding affects only one part of a geosyncline, which then passes into a quasicratonic state while adjacent parts still continue to subside. This changes simultaneously the type of magmatism and the region of its manifestation. Especially significant complications occur during the middle stages, i.e., at the time of the most intensive folding. A particularly clear illustration of this is the middle stage of the Alpine cycle, which included several phases of folding differing in extent and sometimes partially overlapping because of the gradual development of the folded zone. This face determined the great variation in composition of the igneous rocks formed during this stage. Depending on the geological setting of their formation, they present the characteristics of deep-seated, very uniform, granite batholiths or of hypabyssal intrusives with strong Pacific type characteristics and a large range of differentiation, or as in the case of the Alpine cycle, the igneous rocks form small intrusions of extremely variable composition ranging from pyroxenites to very acid granites and syenites. Evidently in the case of a great variety of intrusive rocks, assimilation plays an important role, and it also influences the associated mineralization.

Similar complications occurred during the formation of the above-mentioned leucocratic granites of the initial stage of development of the Jurassic geosyncline and during the Upper Cretaceous andesite-trachyte volcanism coinciding with the geosynclinal regime in the Srednegor'ye structural belt. The explanation of these complications must be sought by profound analysis of the entire geological setting and of the composition of the corresponding magmatic complexes. The very fact that these problems arise helps further development of the proposed schemes and makes it easier to solve the problem of the general pattern of the development of magmatic activity, tectonics and metallogeny in folded regions.

REFERENCES

1. Abdulayev, Kh.M., DAKYI I ORUDNENIYE [DIKES AND MINERALIZATION]: Gosgeolizdat, 1957.

2. Afanas'yev, G.D., OSNOVNYYE ITOGI IZUCHENIYA MATMATICHESKOY GEOLOGII SEVERO-KAVKAZSKOY SKLADCHATOY OBLASTI [SUMMARY OF THE IGNEOUS GEOLOGY OF THE NORTH CAUCASIAN FOLDED REGION]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 3, 1956.

3. __________, O KAYNOZOYSKOM MAGMATIZME KAVKAZA I O NEKOTORYKH ITOGAKH OPREDELENIYA ABSOLYUTNOGO VOZRASTA KAVKAZSKIKH POROD K-AR METODOM [CENOZOIC IGNEOUS ACTIVITY IN THE CAUCASUS AND CERTAIN RESULTS OF ABSOLUTE AGE DETERMINATION OF CAUCASIAN ROCKS BY THE K/A METHOD]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 6, 1957.

4. __________, O NEKOTORYKH GEOLOGICHESKIKH PROBLEMAKH PETROLOGII [ON CERTAIN GEOLOGICAL PROBLEMS OF PETROLOGY]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 11, 1957.

5. Bilibin, Yu.A., METALLOGENICHESKIYE PROVINTSII I METALLOGENICHESKIYE EPOKHI [METALLOGENETIC PROVINCES AND EPOCHS]: Gosgeolizdat, 1955.

6. Dmitrov, Str., SOSTOYANIYE I OCHEREDNYYE ZADACHI IZUCHENIYA MAGMATICHESKIKH I METAMORFICHESKIKH KOMPLEKSOV BOLGARII [THE STATE OF KNOWLEDGE AND THE CURRENT PROBLEMS IN THE STUDY OF THE IGNEOUS AND METAMORPHIC COMPLEXES OF BULGARIA]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 1, 1955.

7. __________, POSTIZHENIYA I ZADACHI NA PETROGRAFSKITE IZUCHVANII U NAS [THE ACHIEVEMENTS AND PROBLEMS OF PETROGRAPHIC INVESTIGATIONS IN OUR COUNTRY]: Godishnik na Sof. un-t, fiz.-mat. fak., 1939.

8. __________, MAGMATICHNITE I METAMORFNITE SKALI V B"LGARIYA. OSNOVI NA GEOLOGIYATA NA B"LGARIYA [IGNEOUS AND METAMORPHIC ROCKS OF BULGARIA. FUNDAMENTALS OF GEOLOGY OF BULGARIA]: Godishnik na Dir. za geolozhki i minchi prouchvaniya otd. A, t. 4, 1946.

9. Kotlyar, V.N., O MAGMATICHESKIKH KOMPLEKSAKH I ORUDNENII [IGNEOUS COMPLEXES AND MINERALIZATION]: Sov. Geol., sb. 43, 1955.

10. Serpukhov, D.I., OBSHCHIYE PRINTSIPY REGIONAL'NOGO METALLOGENICHESKOGO ANALIZA [GENERAL PRINCIPLES OF REGIONAL METALLOGENETIC ANALYSIS]: Sov. Geol., sb. 43, 1955

11. Kostov, Iv., MAGMATIZ"M I RUDOOTLAGANE V YUGOIZTOCHNA EVROPE [IGNEOUS ACTIVITY AND ORE DEPOSITION IN SOUTHEASTERN EUROPE]: Godishnik na Sof. un-t, fiz. fak., t. 13, kn. 3. est. istoriya, 1945-46.

12. Petraschek, W.F., GEBIRGSBILDING, VULKANISMUS UND METALLOGENESE IN DEN BALKANIDEN UND SÜDKARPATHEN: Fortschr. Geol. und Paleontol. Bd. 14, H. 47, 1942.

13. __________, DIE JUNGEREN TEKTONISCHEN UND MAGMATISCHEN PHASEN IM GEBIRGSZÜGE KARPATHEN -- BALKAN: Sitzungsber. Österr. Akad. Wiss., math.-naturwiss, Kl. M Abt. I, Bd. 7, 158, H. 8, 1949.

14. __________, BEZIEHUNGEN ZWISCHEN DER ANATOLISCHEN UND DER SÜDOSTEUROPÄISCHEN METALLPROVINZ: Mad. Tekt. ve Arama enst. dergisi, no. 46-47, Ankara, 1955.

15. __________, GROSSTEKTONIK UND ERZVERTEILUNG IN MEDITERRANEAN KETTENSYSTEM SITZUNGSBER. Österr. Akoq. Wiss. math.-naturwiss. Kl., Abt. I, Bd. 164, H. 3, 1955.

16. __________, DIE OSTMEDITERRANE UND DIE ALPINE ERZPROVINZ: Berg- und Huttenmann. Monatsch., H. 2, 1956.

17. Stille, H., MAGMATO-TEKTONISCHE VERHÄLTNISSE BULGARIENS IM LICHTE ALLGEMEINEN ERFAHRUNGEN.

Bulgarian Academy of Sciences
Sofiya

Received May 4, 1959

CATAGENESIS[1]

by

A.I. Perel'man

> "The phenomena of catagenesis are exceptionally interesting and important from the geochemical point of view. . . . This term, introduced by me into geochemistry in 1922, is not yet generally accepted, yet the vast cycle of geochemical processes embraced by it still remains unstudied."
>
> — A.E. Fersman, Geokhimiya, v. 2, 1934, p. 294.

The study of supergene processes has always been one of the main objects of geochemistry. It has grown in importance in recent years in connection with the extensive development of geochemical methods of prospecting whose theory is based essentially on the laws of supergene migration of elements. A considerable role in increasing interest in supergene processes has been played by the idea that a whole group of very large ore deposits may be of supergene origin. Many features of supergene processes are now being studied thoroughly and from many points of view. There are, however, certain processes of the supergene cycle which have been only slightly touched upon by geochemical thought. One of these is catagenesis, a concept introduced to science by A. E. Fersman in 1922. In 1934 he wrote, ". . . by catagenesis I mean the totality of chemical transformations of sediment after it became separated from the water of the basin by a layer of later deposit and up to the moment when it became part of the surface of a continent, i.e. when it became exposed to the atmosphere. . . . Catagenesis is related to the exchange of solutions between petrographically and geologically different layers or horizons. The main participants in this process are oxygen, carbonic acid and water, and, in part, silica, sulfuric acid solutions, etc. . . . . The results of the process are cavities with calcite dripstone (stalactites), secondary concretions, fractures filled with calcite or quartz, silicification, enrichment in magnesium and formation of dolomite, palygorskite, etc. ...." [14].

The principal agent of catagenesis is ground water migrating over relatively short distances within the boundaries of rock contacts. New mineral bodies are formed also as a result of more extensive migration of subsurface solutions, but this process Fersman proposed to call hydrogenesis.

Inasmuch as catagenesis and hydrogenesis as understood by Fersman are caused by the same agent and it is difficult to draw a boundary between them, we propose to use, from now on, only the term catagenesis and to broaden its interpretation to include all changes in rocks produced by ground water in the supergene zone.

The catagenetic processes are of great geochemical importance. During geological history, ground waters have performed a vast chemical labor in the earth's crust and in many cases radically reworked the sedimentary rocks. These processes are responsible for the formation and destruction of ore deposits, for the alteration halos around ore bodies, for the chemical composition of ground waters and for many other geological phenomena of practical importance. It is easy to understand why these processes interest hydrogeologists, mineralogists, geochemists and other specialists (see the works of A.M. Ovchinnikov, V.A. Sulin, F.A. Makarenko, N.M. Strakhov, L.B. Rukhin, D.G. Sapozhnikov, N.V. Logvinenko, L.V. Pustovalov and others). But still the catagenetic processes are far from being well known, and a number of phenomena related to them have remained almost untouched by scientific investigation.

The geochemical study of these processes initiated by Fersman should be of the greatest

[1]Katagenez.

importance in extending our knowledge of them. In the present paper, certain general problems of the geochemistry of catagenesis will be discussed on the basis of the author's material from the Russian platform, Kazakhstan and Middle Asia.

The characteristic feature of catagenesis is the irregularity of its distribution in the strata and its localization in definite horizons, beds and structures. Catagenesis develops mainly in aquifers and at their contacts with impermeable strata, while the central parts of the latter may be relatively little changed. Thus in the zone of catagenesis, side by side with strongly altered rocks there may exist large "sealed off" blocks of unchanged or slightly changed rock.

In studying the various catagenetic phenomena, it is not difficult to show that each of them is characterized by the presence of certain elements whose migration is the geochemical feature of the given type of catagenesis. These elements (ions and chemical compounds) we shall call typomorphic.

Among the typomorphic elements, ions and compounds participating in catagenesis, are free oxygen, CO_2, H_2S, Cl^-, SO_4^{2-}, Na^+, Ca^{2+} and others. In the author's opinion, the migration of typomorphic elements must become the basis for the geochemical study and geochemical classification of catagenetic processes.

The greatest role in catagenesis is played by those elements which migrate actively under the given conditions and are capable of a certain amount of concentration. For this reason, such a sluggish element as titanium, for example, has little effect on the geochemistry of catagenesis, although its clarke is high. We may formulate a principle of mobile components according to which the geochemical characteristics of catagenesis are determined by the elements which migrate actively but at the same time have a tendency towards accumulation, i.e., by typomorphic elements.

Two main groups of typomorphic elements may be established. The first group includes typomorphic elements and compounds migrating in gaseous form: oxygen, carbon dioxide, hydrogen sulfide, methane and others. Their effect in catagenetic processes is especially great and often they determine the geochemical characteristics of a given type of catagenesis. The geochemical role of gases was first emphasized by V.I. Vernadskiy [1], and later his ideas were developed by Ovchinnikov in his geochemical classification of ground waters [4]. The gases particularly affect the oxidation-reduction environment in which the catagenetic processes take place.

According to the composition of the gaseous migrants, three principal catagenetic environments must be distinguished:

1. The oxidizing environment. Water contains free oxygen. Catagenesis takes place in an oxidizing environment with all its geochemical characteristics. The typomorphic element is oxygen.

2. Reducing environment without H_2S. The waters contain no free oxygen nor other strong oxidizers, are rich in CO_2 and locally in methane and other hydrocarbons, but contain little or no H_2S. Under these conditions, iron and manganese migrate easily (as Fe^{2+} and Mn^{2+}).

According to A.V. Shcherbakov [16], iron may migrate in waters containing not more than 95 to 105 mg/l H_2S, but with higher H_2S content, all iron is precipitated as sulfides. The typomorphic gases are CO_2 and, locally, hydrocarbons.

3. The reducing hydrogen sulfide environment. The waters do not contain free oxygen or other strong oxidizers but are rich in hydrogen sulfide and, locally, in methane and other hydrocarbons. Under these conditions, iron and many other metals do not migrate but form difficultly soluble sulfides. The typomorphic compounds are hydrogen sulfide and, in part, hydrocarbons.[2]

The other group of typomorphic elements includes elements and compounds migrating in water in true solution or in colloidal suspension. These are: chlorine, sulfate and bicarbonate ions, calcium, magnesium, sodium, silicon and others. The water migrants also have a great effect on catagenesis and in many cases determine its character.[3]

The typomorphic elements migrating in water determine to a considerable degree the alkaline or acid character of waters and their salinity.

Each geochemical type of catagenesis is characterized by a definite combination of gaseous and water migrants present together in the waters and together affecting the rocks.

---

[2]It should be stressed that the difference between the second and third environments is determined not only by the value of the oxidation-reduction potential. It may have the same value in both, but the presence or absence of H_2S makes the conditions of migration very different.

[3]The gaseous migrants can also be carried in aqueous solutions as ions or molecules (for example, oxygen in Na_2SO_4, carbon in Na_2CO_3). But it is typical of them to migrate in the gaseous state (including dissolved gases) while the water migrants seldom or never migrate in the gaseous state.

On this basis a geochemical classification of catagenesis may be built whose principle is clear from Table 1. The table shows only a few types of catagenesis, but the above principles of classification may be used to separate other types and to construct a more detailed classification of catagenetic processes within each type (subtypes, species, etc.).

The types of catagenesis given in Table 1 are usually readily identified in geologic sections. In most cases they are represented by elongated zones (ancient water-bearing horizons) carrying secondary products of one kind or another. Often they are identified by the bluish-gray or greenish color against a brown or red background, by the presence of horizons of accumulation of calcite and soluble sulfates, by silicification, iron oxide crusts, etc. In most cases the ancient water-bearing horizons are easily distinguished by their structural features (for example a sandy layer in clays, etc.). These features have been studied little so far, although in many regions sedimentary rocks are very strongly altered by ground waters. In a number of cases the secondary features due to catagenesis have been regarded as indicators of special conditions of sedimentation, either syngenetic or diagenetic.

It is impossible within the scope of this paper to characterize all geochemical types of catagenesis mentioned above. Below, we shall explain them briefly and dwell in detail only on types three, five and eight.

"Sulfuric acid" catagenesis (type 1) develops when rocks containing sulfides or free sulfur come in contact with oxygenated ground waters. The result is formation of sulfuric acid, lowering of the pH of the ground water to 3-4 and sometimes to 1-2, intensive migration in the waters of many elements which are little mobile under other conditions, such as Al^{3+}, and the deposition of secondary minerals (Jarosite, alunite, alums and others). These phenomena have been well investigated in the regions of sulfide mineralization [11].

Acid catagenesis (type 2) is accomplished by weakly acid oxygenated waters (pH 4-6) containing CO_2 and locally organic acids. These waters produce less rock alteration than do the sulfuric acid solutions. The catagenetic processes of this type have been studied little as yet. Iron and aluminum show little mobility in acid catagenesis. This type of catagenesis is characterized by formation of clays (especially hydromicas, kaolinite and halloysite). In carbonate-free rocks similar processes occur under moist climate conditions.

Acid gley (type 3) and carbonate gley (type 5) types of catagenesis are separated here for the first time. Their extensive development was established by the author during a study of the redbeds in Middle Asia (C, Cr, Pg, N),

Table 1

Some Geochemical Types of Catagenesis
(Based on Typomorphic Elements, Ions and Compounds)

Alkalinity or acidity of environment	Typomorphic water migrants	Typomorphic air migrants		
		O_2 (oxidizing environment)	CO_2, partly CH_4 (reducing environment, H_2S absent)	H_2S (reducing environment, H_2S present)
Strongly acidic	H^+, SO_4^{2-}; sometimes Al^{3+}, Fe^{3+}	1. Sulfuric acid	—	—
Weakly acidic	H^+, organic acids, Ca^{2+}	2. Acid 4. Calcium carbonate	3. Acid gley 5. Carbonate gley	—
Neutral and weakly alkaline	Cl^-, SO_4^{2-}	6. Saline		7. Saline-sulfide
Strongly alkaline	OH^-; Na^+; HCO_3^-; SiO_2	8. Sodium carbonate	—	9. Sodium carbonate-hydrogen sulfide

Kazakhstan (C_1, Cr) and on the Russian platform (Preural'ye, Donbass).[4] In all these regions, the now waterless redbeds exhibit catagenetic alteration caused by former ground water activity.

The water-bearing horizons were localized in the coarser-grained rocks (sands and gravels), while the silts and clays served as the impermeable beds. Sometimes the aquifers were fractured limestones enclosed in clay-silt sequences (Figs. 1 and 2).

The color of the redbeds is due to the film of oxides and hydrous oxides of iron on individual grains of sand, silt or clay. The occurrence of iron in such "films" suggests that it easily passes into solution when the environment changes from the oxidizing to the reducing.

The migration of iron in a reducing medium is very characteristic of modern swamps in the wet climatic zones of the earth (wet tropics, tundra, taiga, etc.). It is known that as a result of removal of iron the inorganic layers on a swamp bottom acquire a bluish-gray or a variegated ocher-bluish-gray color. The equivalent modern process has been studied in detail and is known as gleying. Our investigations show that the gleying is very clearly recorded in redbeds and that it had the same characteristics as in the modern swamps. However, in the redbeds it was connected not with surface soil processes (formation of bogs) but with the presence of ground waters in the beds and between them. According to the geological data, these waters in some cases existed several hundred meters below the surface.

The probable mechanism of catagenetic gley formation was as follows: The water of the water-bearing horizons enclosed in the redbeds apparently contained CO_2 rather than oxygen and was capable of reducing Fe^{3+}. The sands, gravels and other water carriers were subjected to the process of gley formation, and their iron was reduced to Fe^{2+} and was removed as $Fe(HCO_3)_2$. As a result, the iron content in the ancient aquifers was decreased and they acquired the green or bluish-gray color (sometimes with occasional ocherous spots) which now stands out strikingly against the brown, red or yellow background of the enclosing rocks.

The upper and lower horizons of the impermeable rocks (for example, clay) were partially wetted by capillary action and were also subjected to the gleying process; their iron was reduced and migrated into the water-bearing layers of sand and beyond. As a result, the clays and other impermeable rocks at the contact with the water-bearing beds were also turned into gley and acquired green, purple or bluish-gray color, which extended in tongues through the intermediate variegated zone into the unaltered red clays and silts. Thus, such spotted gley zones one meter and more in thickness, frequently found in sedimentary rocks, are signs of former groundwater activity.

Gley occurs both in carbonate-free ("acid gley catagenesis") and in carbonate-bearing redbeds. In the first case, manganese, calcium, iron, phosphorus and other

[4] The catagenetic gley formation occurs in other rocks than redbeds (for example, in the Quaternary alluvium of Middle Asia and in the Neogene sands of Priazov'ye, etc.).

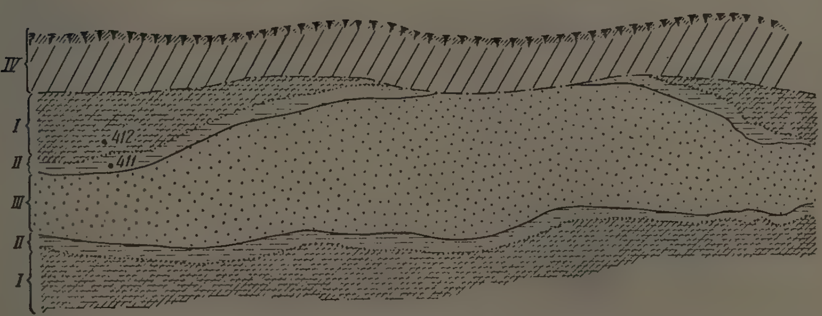

FIGURE 1. Acid gley catagenesis in Senomanian siltstones of the Zerabulak Mountains. Scale: 1:30

I -- Crimson siltstones; II -- green siltstones - gley; III -- gray, locally brownish sandstone - an ancient aquifer; IV -- Quaternary deposits; 411, 412 -- sampling points; analyses of samples are given in Table 2.

elements[5] (Table 2) were intensively removed from the rock. In the carbonate gley catagenesis, the elements migrated less intensively, but even so, iron, phosphorus, manganese and other elements were removed (Table 3). Iron and manganese leached out of the gley horizons were concentrated locally in neighboring areas within the same aquifers (Fig. 2).

Gley formation is most intensive in strata consisting of thin beds (not over a few meters) of claystones and siltstones alternating with beds of sandstones and conglomerates. The homogeneous thick sequences (hundreds and tens of meters) of sandstones, conglomerates or claystones usually have weakly developed gley or none at all. The phenomena of gley development are very characteristic of the copper-bearing sandstones which usually occur in the redbeds.

Our investigations have shown that the ore in the copper-bearing sandstones of Priural'ye, Donbas and Central Asia and in the large economic deposit of the U.S.S.R. at Dzhezkazgan are localized in the gley horizons of the redbeds. It is not quite clear yet what role gleying plays in the migration and concentration of copper. The deposits of a number of other useful minerals occurring in redbeds also are characteristically associated with gleying.

Calcium carbonate catagenesis (type 4) is developed in carbonate rocks; the formation of karst may serve as an example. Salt catagenesis (type 6) and salt-sulfide (type 7) catagenesis are due to the action of strongly saline waters containing and lacking in oxygen, respectively. These processes are especially common in dry regions and are characterized by the deposition of salts and gypsum in the rocks.

By soda catagenesis (type 8) are understood those changes in sedimentary rocks which are produced by alkaline groundwaters usually having pH over 8 - 8.5, and sometimes 10 and even 11. The salinity of these waters is usually low and does not exceed 1 g/l. Such waters form under different conditions in nature, as for example in arkose at the expense of its weathering products. The necessary condition is the absence of gypsum from the rock, for its presence prevents formation of large amounts of soda.

The characteristic feature of sodium carbonate water is that many elements, even those which are little mobile in other media,

[5] Assuming that Al was not removed during the process, the relative degree of removal of different oxides was computed. The positive values for SO_3 and other oxides indicate that elements were introduced as well as leached out in the gleying process.

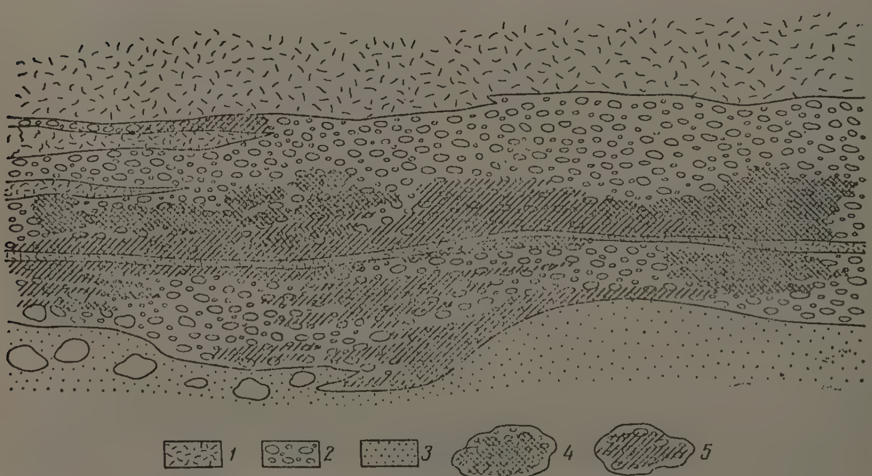

FIGURE 2. Carbonate gley catagenesis in the early Quaternary deposits of the northern foothills of the Turkestan Range (7 km southeast of Mt. Ura-Tyube). Scale: 1:50.

1 -- Loess; 2 -- conglomerate - ancient aquifer; 3 -- sandstone; 4 -- deposition of iron; 5 -- deposition of manganese.

Table 2

Chemical Composition of Crimson Senomanian Siltstones of the Zerabulak Mountains (Uzbekstan) (sp. 412) and of the Green Siltstones Produced from Them by the Development of Gley (sp. 411) (see Fig. 1) (Percent)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Cl	SO_3	H_2O-	H_2O+	CO_2	Total
412	73,67	12,01	3,57	none	0,02	0,70	0,25	0,78	1,47	0,03	0,35	0,19	1,07	4,89	0,48	99,51
411	73,04	13,37	1,72	none	traces	0,86	0,01	0,85	1,40	0,02	0,25	0,62	1,64	4,32	0,60	99,01
Relative degree of leaching	−10,76	0,00	−56,86	none	≈100	+10,0	−96,4	−2,56	−14,28	−40,0	−37,14	+194,73	—	—	—	—
	Intensity of leaching: Mn > Ca > Fe > P > Cl > K > Si > Na > Al (O).															

Table 3

Chemical Composition of Red Dolomitic Siltstones of the Lower Cretaceous Al'muradskaya Formation (sp. 122) and of the Green Siltstones of the Same Formation (sp. 120) Produced by the Development of Gley. Kugitant River Valley, Turkmeniya (Percent)

Sample No.	SiO_2	Fe_2O_3	FeO	Fe_2O_3–FeO given as Fe_2O_3	MnO	Al_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Cl	CO_2	Loss on ignition	Total
122	34,44	2,51	1,30	3,94	0,11	9,44	12,90	12,85	2,22	0,57	0,11	0,20	0,02	19,08	22,88	99,35
120	43,50	3,10	0,50	3,65	0,08	12,07	8,14	9,95	2,65	1,35	0,14	0,85	0,47	12,16	16,92	97,87
Relative degree of leaching	−1,16	—	—	−21,9	−45,4	0,00	−50,7	−39,6	−7,20	+84,1	−9,9	+230	+1700	—	—	—
	Intensity of leaching: Ca > Mn > Mg > Fe > P > K > Si > Al (O).															

NOTE: Comma represents decimal point.

become highly mobile in it. This is due, to a large extent, to the formation of easily soluble carbonate complexes. For example, in a soda-rich medium, uranium forms an easily soluble complex of the $Na_4 [(UO_2)(CO_3)_3]$ type and can migrate over long distances. the low solubility of the basic copper carbonates is responsible for the existence of malachite and azurite, but it was shown by V.V. Shcherbina and L.I. Ignatova [17] that in soda solutions copper forms easily soluble complexes similar to those of uranium. Analogous complexes are formed in soda-rich media by such sluggish elements as zirconium, scandium and the yttrium earths (yttrium, gadolinium and others). The cerium earths, on the other hand, have low mobility in the soda-rich media. Beryllium and silver also form soluble complexes with sodium carbonate. Vanadium and molybdenum migrate readily in a sodium carbonate environment and the solubility of silica increases. Under alkaline conditions aluminum forms easily soluble sodium aluminates and becomes mobile.

There is, then, a possibility that a considerable number of elements (U, Cu, Ag, Mo, V, Si, Al, Y, Sc, Zr and Be) may be extracted from rocks by soda-rich waters, migrate together and be precipitated in the areas where, for one reason or another, the composition of the water changes.

The signs of soda catagenesis in sedimentary rocks and ores are, first of all, the paragenetic associations of elements in different secondary products (cement in sandstones, concretions, etc.). It is clear that not all of the above-mentioned elements will be present on every occasion, for not all of them are likely to be present in suitable form or large enough amount in the rocks or in the provenance area of soda-rich waters. But even if only some of these elements are present together, soda catagenesis may be suspected (for example if uranium, zirconium, vanadium, molybdenum and yttrium earths are found together). Another indication of soda catagenesis is intensive migration of silicon manifested in the silicification of the rocks (secondary quartz, opal, chalcedony, agatized wood) and in the corrosion of quartz grains and feldspars, usually easily detected under the microscope. The migration of aluminum and silicon together produces aluminosilicates of the palygorskite type, which was regarded by Fersman as a characteristic catagenetic mineral. The secondary albitization of rocks may also be due to this process, as well as the formation of brucite, $(Mg(OH)_2$, which is precipitated from strongly alkaline solutions.

All these features of soda catagenesis in sedimentary rocks and ores may be established by macroscopic and microscopic study. It is possible that the processes of soda catagenesis played an important role in the formation of epigenetic ore bodies of a number of sedimentary ore deposits. For instance, the participation of catagenetic processes in the formation of ore bodies in some cupriferous sandstones is very probable.

Each type of catagenesis is characterized in the geological section by its typical "profile" with a special color and complex of secondary minerals. The formation of ore deposits (copper, uranium, sulfur, nickel and others) is related to many of these processes. The ore-bearing strata in such cases are alternating beds of different permeability, and the ore bodies are localized in the permeable rocks or in the rocks which were water-bearing in the past. Such rocks are conglomerates, gravels, sands, sandstones and jointed limestones. The impermeable rocks separating them — clays, massive argillaceous limestones and siltstones — are usually barren.

The alternation of permeable and impermeable strata is especially favorable to the formation of ore deposits if the thickness of each kind of strata is not too great, not over a few meters or a few tens of meters. According to the available data, thick sequences of permeable rocks, measuring hundreds and more meters, are largely unfavorable to the formation of ore deposits. The ore bodies in sedimentary rocks are usually deposited in the zone of sharp change of physico-chemical conditions in the water-bearing horizon. Such zones appear in the areas where ground waters of different composition meet, or in areas of abrupt change in lithology. The mineralogy of the rocks and ores ofter permits reconstruction of the character of this boundary and reveals the cause of concentration of ores. For example, acid or slightly alkaline metal-bearing waters may meet hydrogen sulfide along their route (or hydrogen sulfide waters, gases containing H_2S, or decaying organic matter). The metals which form insoluble sulfides and some others will be precipitated. The presence of epigenetic sulfides is a sign that H_2S once appeared in the water-bearing horizon.

It would seem that in geological mapping and prospecting and in special lithological investigations it is necessary now to pay attention to the catagenetic phenomena in sedimentary strata.

The reconstruction of the chemical peculiarities of ground waters of the past geologic epochs has a great theoretical and practical significance; it explains the process of ore formation and may be used in developing new prospecting methods. At present paleohydrogeology is still relatively undeveloped. In most cases we judge of the hydrogeologic and

hydrochemical characteristics of the past epochs on the basis of indirect evidence (salts and gypsum — dry climate and, therefore, saline waters; iron ores, bauxite, coal — moist climate and waters of low salinity). Such indirect data lead only to the most general deductions and do not reveal the geochemical characteristics of the individual water-bearing horizons which existed in the past geologic periods.

By studying the secondary products of the ancient aquifers, especially their chemical composition, it is possible to reconstruct the chemical characteristics of the ground waters which flowed through them. Knowing the conditions of migration and precipitation of the elements, it is possible, with greater or less accuracy, to reconstruct the physicochemical character of the waters in which the elements migrated and from which they were precipitated. Of especial interest is the chemical analysis of manganese hydroxides, which have high adsorbing capacity and can extract from water a number of metals — copper, nickel, cobalt, lead, zinc and others. By determining the content of these metals in the manganese dioxide films, an idea may be obtained of the content of these metals in the ancient waters. Very probably, a general metallogenetic characteristic of a given region can be obtained in this way.

It is well known that the hydrochemical method of prospecting is of great value in locating concealed ore bodies. Unfortunately, its use is limited to the existing water-bearing horizons and surface drainage. The hydrochemical method in its present form cannot be used in regions which are now arid. But very likely these regions contained ground waters in the past, and these waters must have left their traces in the rocks in the form of different secondary products. By studying the chemical composition of these catagenetic products it is possible to reconstruct the chemical composition of the ancient waters and, in effect, make a search for ore. In other words, it is probable that in this way the ancient dispersion halos once formed by ground water around ore bodies may be reconstructed and the deposits themselves located.

It is proposed that the method of prospecting based on the study of the minerals of the ancient aquifers be called the paleohydrochemical method. The preceding discussion gives only the principles underlying this method.

The areal distribution of catagenetic processes may be shown on special maps ("catagenesis type maps") which should range from reconnaissance to large-scale maps. The theoretical value of such maps seems unquestionable. They will permit reconstruction of the geochemical conditions of past geological epochs and, in particular, of the characteristics of their ground waters. Inasmuch as the formation of many economic deposits in a number of localities is related to a particular type of catagenetic process, such maps may be used in prospecting.

Thus, Fersman's idea, developed almost 40 years ago, is justified, that catagenesis is of great geochemical importance.

A detailed study of the varied catagenetic processes is one of the urgent projects of geochemistry.

REFERENCES

1. Vernadskiy, V.I., ISTORIYA MINERALOV ZEMNOY KORY, T. 2. ISTORIYA PRIRODNYKH VOD [HISTORY OF MINERALS IN THE EARTH'S CRUST, V. 2. HISTORY OF NATURAL WATERS]: Goskhimizdat, ch. i, vyp. i, 1933; vyp. 2, 1934; vyp. 3, 1936.

2. Kossovskaya, A.G., N.B. Logvinenko and V.D. Shutov, O STADIYAKH FORMIROVANIYA I IZMENENIYA TERRIGENNYKH POROD [STAGES OF FORMATION AND ALTERATION OF CONTINENTAL DEPOSITS]: Doklady, Akademiya Nauk SSSR, t. 116, no. 2, 1957.

3. Logvinenko, N.V., O POZDNEM DIAGENEZISE (EPIGENEZISE) DONETSKIKH KARBONOVYKH POROD [LATE DIAGENESIS (EPIGENESIS) OF THE CARBONACEOUS ROCKS OF THE DONETS REGION]: Izvestiya, Akademiya nauk SSSR, ser. geol., no. 7, 1957.

4. Ovchinnikov, A.M., OBSHCHAYA GIDROGEOLOGIYA [GENERAL HYDROGEOLOGY]: Gosgeoltekhizdat, 1955.

5. Popov, V.M., YAVLENIYA DIAGENEZA I EPIGENEZA V MEDISTYKH PESCHANIKAKH DONETSKOGO BASSEYNA [THE PHENOMENA OF DIAGENESIS AND EPIGENESIS IN THE CUPRIFEROUS SANDS OF THE DONETS BASIN]: Izv. Kirg. fil. Akademiya Nauk SSSR, vyp 1 (11), 1954.

6. ___________, O NEKOTORYKH SPETSIFICHESKIKH OSOBENNOSTYAKH GEOLOGII MEDISTYKH PESCHANIKOV TSENTRAL'NOGO KAZAKHSTANA [CERTAIN SPECIFIC FEATURES OF THE CUPRIFEROUS SANDSTONES OF CENTRAL KAZAKHSTAN]: Tr. In-ta geol. Akademiya Nauk Kirg. S.S.R., vyp. 6, 1955.

7. Pustovalov, L.V., VTORICHNYYE IZMENENIYA OSADOCHNYKH GORNYKH POROD I IKH GEOLOGICHESKOYE ZNACHENIYE [SECONDARY CHANGES IN SEDIMENTARY ROCKS AND THEIR GEOLOGICAL SIGNIFICANCE]: V sb. O vtorichn. izmenen. osad. porod (In the book: Secondary changes in sedimentary rocks). Akademiya Nauk SSSR, 1956.

8. Rukhin, L.B., OSOBENNOSTI EPIGENEZA MELOVYKH OTLOZHENIY FERGANSKOY KOTLOVINY [CHARACTERISTICS OF EPIGENESIS OF CRETACEOUS DEPOSITS OF THE FERGANA BASIN]: Uch. zap. LGU, ser. geol., vyp. 7, 1956.

9. __________, O NEKOTORYKH ZAKONOMERNOSTYAKH EPIGENEZA [CERTAIN REGULARITIES OF EPIGENESIS]: V sb. Vopr. Mineralogii Osad. Obrazovaniy, kn. 3 i 4. Izd. L'vovsk. un-ta, 1956.

10. Sapozhnikov, D.G., O STADIYAKH OSADOCHNOGO RUDOOBRAZOVANIYA [STAGES OF ORE DEPOSITION]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 2, 1955.

11. Smirnov, S.S., ZONA OKISLENIYA SUL'FIDNYKH MESTOROZHDENIY [THE OXIDIZED ZONE OF SULFIDE DEPOSITS]: 3-ye izd. Akademiya Nauk SSSR, 1955.

12. Strakhov, N.M., O TEORETICHESKOY LITOLOGII I YEE PROBLEMAKH [THEORETICAL LITHOLOGY AND ITS PROBLEMS]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 11, 1957.

13. Tatarinov, P.M., USLOVIYA OBRAZOVANIYA MESTOROZHDENIY RUDNYKH I NERUDNYKH POLEZNYKH ISKOPAYEMYKH [CONDITIONS OF FORMATION OF METALLIC AND NON-METALLIC ORE DEPOSITS]: Gosgeoltekhizdat, 1955.

14. Fersman, A.E., GEOKHIMIYA [GEOCHEMISTRY]: t. 2, Gosizdat, 1934.

15. __________, GEOKHIMIYA ROSSII [GEOCHEMISTRY OF RUSSIA]: Goskhimtekhizdat, 1922.

16. Shcherbakov, A.V., GEOKHIMICHESKIYE KRITERII OKISLITEL'NO- VOSSTANOVITEL'NYKH OBSTANOVOK V PODZEMNOY GIDROSFERE [GEOCHEMICAL CRITERIA OF ENVIRONMENTS IN THE SUBSURFACE HYDROSPHERE]: Sov. geologiya, sb. 56, 1956.

17. Shcherbina, V.V. and L.I. Ignatova, NOVYYE DANNYYE PO GEOKHIMII MEDI V ZONE GIPERGENEZA [NEW DATA ON THE GEOCHEMISTRY OF COPPER IN THE SUPERGENE ZONE]: Zap. Vses. mineralog. o-va, ser. 2, ch. 84, vyp. 3, 1955.

Institute of Geology of Ore Deposits,
Petrography, Mineralogy and Geochemistry
Academy of Sciences, U.S.S.R.
Moscow

Received January 7, 1959

ON THE REGULARITIES OF DISTRIBUTION OF MOLYBDENUM AND URANIUM IN MINERALIZED ZONES[1]

by

V. I. Rekharskiy

In the geologic literature are references to the presence of molybdenite in uranium deposits of Shinkolobwe [5], Eldorado [13], British Columbia [14] and others. Conversely, pitchblende and uraninite are found in some molybdenite deposits. But, in spite of the association of these minerals, many questions of the relationship between them and, especially, of their paragenesis, remain incompletely answered, judging by the data in the literature.

It is natural, therefore, that on finding molybdenite and pitchblende in the same mineralized zones, the author's attention was attracted by the relationship between these minerals and the pattern of their distribution. These problems are the more interesting because the elements of these minerals belong to the same subgroup of the periodic table and therefore possess many similar characteristics. Moreover, tungsten, which also belongs to this subgroup, not only forms compounds which commonly occur with molybdenum compounds but also forms paragenetic associations with them [2].

In the course of his study of mineralized zones, the author established the existence of molybdenite-pitchblende paragenesis and determined some of the characteristics of distribution of these minerals.

The mineralized zones referred to are belts of hydrothermally altered rocks which in the overwhelming majority of cases are localized in Paleozoic acid intrusives and extrusives, mainly rhyolites, quartz porphyries, felsites, quartz syenite porphyries and dacite porphyries. The mineralized zones are controlled by extensive fractures connected by series of anastomosing, extremely thin cracks.

These minute cracks in the mineralized zones and the hydrothermally altered enclosing rocks contain pyrite, molybdenite, pitchblende, calcite, galena, sphalerite, chalcopyrite, sericite, quartz, albite, fluorite, barite and, very infrequently, other minerals. In intimate association with the vein and ore minerals are metasomatic minerals among which quartz, sericite, albite, carbonate (mainly calcite) are very abundant, and chlorite, less so. Of the minerals mentioned above, molybdenite and pitchblende are most frequently found together, forming molybdenite-pitchblende veinlets (Fig. 1) or colloform bodies which also contain galena, pyrite, sphalerite, calcite and other minerals.

In the bodies of colloidal origin, molybdenite and pitchblende occur as fine-grained or colloform aggregates. The molybdenite, as a rule, forms bands on pitchblende crusts and pods, heals cracks (Fig. 2) and occurs also in emulsion blebs or intricately patterned bands. Not infrequently, aggregates are found in which molybdenite passes gradually into pitchblende through a molybdenite + pitchblende "mixture" (Fig. 3). These "mixtures" are so fine-grained that sometimes the microscope fails to resolve the individual components, even with the highest magnifications.

The "mixtures" occur in a great variety of forms — as massive bodies, nets, traceries, etc. There are also colloform bodies in which thin pitchblende bands alternate with molybdenite bands and both minerals contain minute inclusions of galena (Fig. 4).

It must be assumed that these formations result from coagulation of gels of complex composition which during the process of aging differentiated into different minerals, each with its characteristic structure of microscopic growth.

Calcite, albite and galena are most frequently found in paragenesis with pitchblende; and sericite and quartz, with molybdenite. Pyrite is found in approximately equal amounts in paragenesis with both minerals. Less often, sphalerite, chalcopyrite, fluorite, barite and chlorite are found in paragenesis with pitchblende and molybdenite.

[1] K voprosu o zakonomernostyakh raspredelen'ya molibdena i urana v mineralizovannykh zonakh.

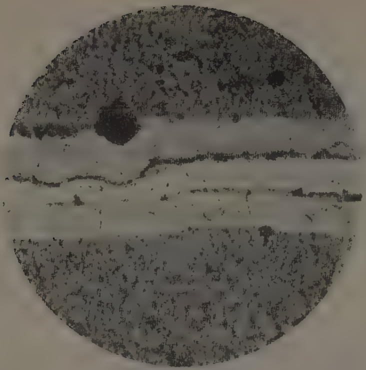

FIGURE 1. Molybdenite-pitchblende veinlet. Molybdenite -- white; pitchblende -- light-gray; rock -- dark-gray.

Polished section; plane polarized light 40X.

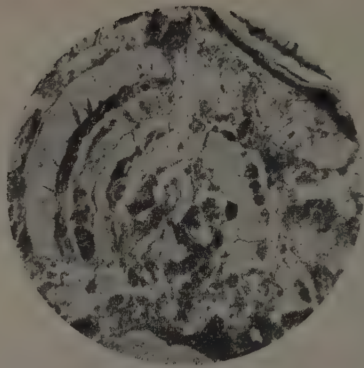

FIGURE 2. Molybdenite (white) filling cracks in a zoned pod of pitchblende (gray). Dark gray -- carbonate.

Polished section; plane polarized light 85X.

Of the carbonates, calcite is the most frequent associate of molybdenite and pitchblende, and ankerite is seldom seen. White or pink calcite forms thin veinlets and, intimately intergrown with sericite and quartz, forms rims about the ore minerals. Together with sericite and quartz, it replaces the dark minerals and oligoclase; and together with albite, orthoclase. In the accumulations of calcite, there are often reniform inclusions of pitchblende, flakes of molybdenite and grains of pyrite and galena.

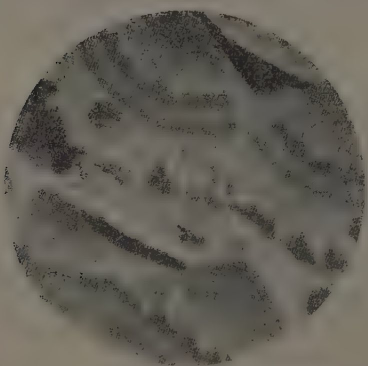

FIGURE 3. Serrated segregations of molybdenite + pitchblende (gray in molybdenite (white). Black -- polishing defects.

Polished section; plane polarized light 410X.

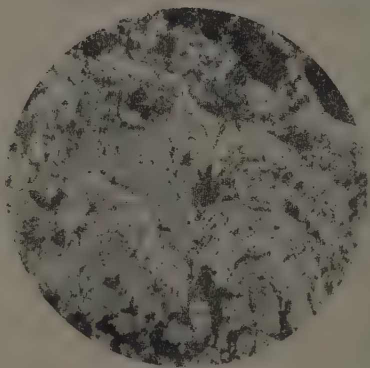

FIGURE 4. Alternation of molybdenite (white and pitchblende (gray) bands. Black -- polishing defects.

Polished section; plane polarized light 106X.

Sericite and quartz replace primary rock-forming minerals, form microscopic veins and, together with calcite and sometimes chlorite, occur as fine-grained aggregates on the periphery of ore minerals. These aggregates contain microscopic grains of molybdenite, pitchblende, pyrite, galena and sphalerite.

Checkerboard albite usually replaces orthoclase, less often oligoclase and, as a rule, is intergrown with the carbonate in the form of irregular aggregates containing ore minerals. Infrequently the aggregates or grains of albite and pitchblende are separated by microscopic bands of carbonate with subordinate sericite, quartz and chlorite. In other cases, the ore minerals are in direct contact with albite grains or occur in them as irregular segregations or lie in the cleavage cracks of polysynthetically twinned albite. These observations indicate, apparently, that the formation of checkerboard albite began before the deposition of the ore minerals and ended during the process.

Chlorite is found but seldom, and usually in the aggregates of sericite, quartz and carbonate.

Pyrite is abundant in veinlets composed of pitchblende, molybdenite, galena and other minerals, occurs as impregnations in the enclosing rocks within the aggregates of sericite, quartz, carbonate, albite, chlorite, and is also often found in microscopic inclusions in calcite, pitchblende, galena and sphalerite and in intimate intergrowths with molybdenite.

Galena forms monomineralic segregations and occurs in intergrowth with pitchblende, pyrite, and sphalerite but seldom with molybdenite. Frequently, it fills dehydration cracks in reniform pitchblende or occurs on them as emulsion blebs or in intricately patterned bands (Fig. 5). Microscopic inclusions of galena are often found in calcite.

Two varieties of sphalerite, marmatite and cleiophane, occur in the veinlets and in the metasomatized rock. Marmatite forms colloform aggregates with minute inclusions of pitchblende, galena, pyrite and blegs of chalcopyrite (Fig. 6). Cleiophane is usually found as small irregular segregations in calcite and fluorite accompanied by pods of pitchblende and inclusions of molybdenite, pyrite and galena.

Chalcopyrite occurs as emulsion blebs in sphalerite or microscopic segregations in the dehydration cracks of pitchblende.

Fluorite and barite are relatively rare. Fluorite is violet or dark violet and contains pods of pitchblende and irregular segregations of molybdenite, pyrite, galena and cleiophane. Occasionally, fluorite and calcite fill dehydration cracks in the pod-like segregations of pitchblende.

Barite occurs in extremely thin hair-like

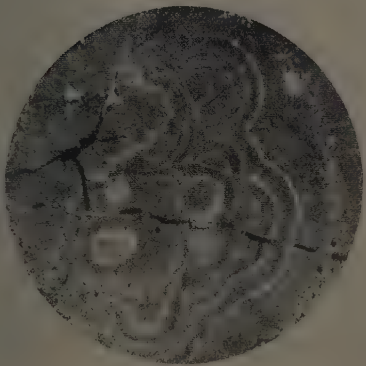

FIGURE 5. Concentric shells of galena (white) in pitchblende (gray).

Polished section; plane polarized light. 106X.

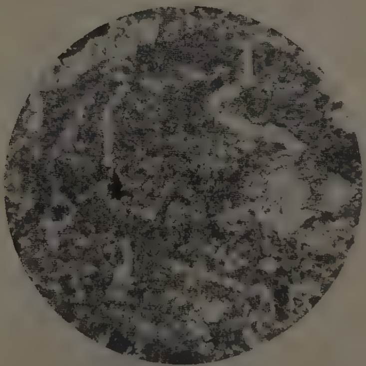

FIGURE 6. Pitchblende segregations of irregular form (light-gray) in sphalerite (dark-gray). Etched with aqua regia. Polished section; plane polarized light. 106X.

veinlets, is pink or milky-white, and is often accompanied by calcite.

The parageneses of these minerals suggest that they were precipitated from solution at approximately the same time and that their formation was closely connected with the hydrothermal alteration of the enclosing rocks. This is confirmed by changes in the pattern of distribution of the minerals with the zonal changes in the enclosing rocks. This dependence is most clearly manifested in the molybdenite-pitchblende paragenesis.

A study of the distribution of molybdenite and pitchblende was made in different mineralized zones which satisfied the following conditions: the mineralization was restricted to rocks of the same composition, and ore, vein and metasomatic minerals were not weathered.

The investigation consisted in mineralogical and petrographical study of thin and polished sections made from samples collected from the zones and along traverses made normal to the strike of the zones. In addition, the material was analyzed chemically and spectrographically (analysts: O.V. Krutetskaya, V.M. Nekrasova and A.S. Dudykina, Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry (IGEM), Academy of Sciences, U.S.S.R.). It should be noted that in some areas of the mineralized zones the inclusions of molybdenite and pitchblende were so small that the quantitative relationship between them could not be determined except by chemical analysis.

The mineralized zones described in this paper are in acid intrusive rocks. The rocks are composed of predominant orthoclase, a smaller amount of quartz, partly sericitized oligoclase, hornblende and pyroxene. These fresh, or more precisely, slightly altered rocks are found at distances of 5 to 15 meters from the mineralized zones.

The intensity of hydrothermal alteration increases towards the zones. At first there is a replacement of the colored minerals by pyrite, chlorite, sericite and, partly, by carbonate and quartz. Then, 2 to 4 meters from the zones, metasomatic minerals begin to predominate over the primary rock-forming minerals. In some areas of the mineralized zones, albite and the commonly associated calcite are widely developed; in others; sericite and quartz. Two principal types of hydrothermal alteration may be distinguished: 1) albitization and carbonatization, and 2) sericitization and silicification.

. The results of chemical analyses agree entirely with the microscopic observations. From the unaltered rocks towards the albitized and carbonatized rocks, the Na_2O/K_2O ratio increases from 0.5 - 0.7 to 1.0 - 7.0, and the potassium content decreases sharply, while the sodium content shows either a slight increase or a slight decrease,[2] related to a considerable development of albite, especially after orthoclase. There is also an increase in the $CO_2/(SiO_2{:}100)$ ratio from 0.9 to 1.3 in the unaltered rock to 1.5 - 2.5 in the altered rock, due to the presence of a considerable amount of carbonate in the latter.

The Na_2O/K_2O ratio decreases from 0.7 - 0.5 in the unaltered to 0.35 - 0.05 in the sericitized and silicified rocks. The content of sodium decreases very sharply because of intensive development of sericite after oligoclase.

Depending on the character of alteration of the rocks and the distribution of the minerals, three kinds of mineralized zones may be distinguished.

The first kind is characterized by extensive development of metasomatic checkerboard albite and of carbonate in the upper part of the zones and of sericite and quartz in the lower. In the lower part, oligoclase is intensively replaced by sericite and, to a less extent, by carbonate, quartz and, rarely, by chlorite. The orthoclase grains are very turbid and their edges are sometimes corroded by aggregates of sericite and quartz. Often the phenocrysts of quartz, orthoclase, sericitized oligoclase and the groundmass of the rock are cut by minute fractures filled with fine-grained sericite (Fig. 7). This type of sericite is also found rather frequently in association with ore minerals and sometimes forms bands separating ore minerals from phenocrysts of the rock-forming minerals partially or completely replaced by metasomatic minerals. In some areas of thin sections gradual transition is observed from coarsely lamellar sericite developed metasomatically after the rock-forming minerals to sericite in fine scales. Evidently, the latter was formed almost synchronously but just a little later than the coarsely lamellar variety. In what follows the finely lamellar sericite will be called second generation sericite.

The Na_2O/K_2O ratio diminishes sharply from 0.7 - 0.5 in unaltered rocks to 0.35 in the sericitized and silicified areas, the sodium content decreases from 3.1% to 2.6%, and the potassium content increases slightly from 5.5 to 6.9% in the same direction.

---

[2] Weight percentages were used in comparing the content of the oxides and their ratios because when the weight per unit volume of the ore minerals is taken into account, the weights per unit volume of the altered and unaltered rocks differ very little in our case.

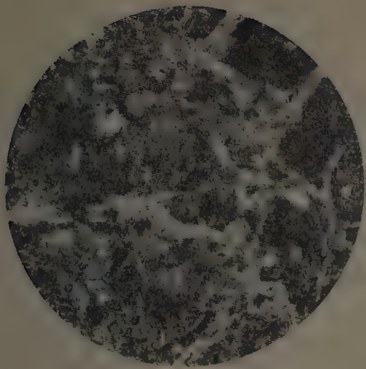

FIGURE 7. Microscopic veinlets of sericite cutting phenocrysts of rock-forming minerals and groundmass (fine-grained).

Thin section; crossed Nicols. 70X.

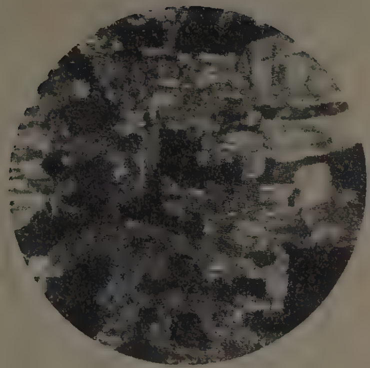

FIGURE 8. Inclusions of pitchblende (black in checkerboard albite (banded).

Polished thin section; crossed Nicols. 150X.

The decrease in sodium content accompanied by increase in potassium content may be explained by the removal of a part of the sodium in the replacement of oligoclase by sericite and by fixation of potassium in second generation sericite.

In the upper parts of the zones there is a noticeable development of sericite and of small amounts of carbonate and quartz after oligoclase and an intensive replacement of orthoclase by albite and carbonate. The inclusions of ore minerals are most commonly associated here with albite, less frequently with sericite, carbonate, quartz and chlorite (Fig. 8).

The difference in the alteration of the rocks in the lower and upper parts of the mineralized zones is especially clearly revealed by petrochemical characteristics (Fig. 9). In the sericitized and silicified rocks $Na_2O/K_2O = 0.35$ and $CO_2/(SiO_2{:}100) = 1.6$, while in the albitized and carbonatized rocks these ratios are 1.1 and 2.2, respectively. It is natural that with increase in the CO_2: SiO_2 ratio the content of calcium should also increase.

Molybdenite and pitchblende are distributed as follows: in the lower parts molybdenite definitely predominates over pitchblende and in the upper parts the proportions of the two minerals are reversed. Chemical analyses confirm the geological-mineralogical observations (Fig. 9). The graphs of the analyses show that the molybdenum content decreases from 3n[3] in the lower parts of the zones to 0.2n[3] in the upper, and the uranium content increases correspondingly from 2.0n to 3.5n.

This indicates that the conditions for accumulation of molybdenum were more favorable in the lower parts of the zones which are characterized by an intensive sericitization of oligoclase, relatively slight alteration of orthoclase and the presence of second generation sericite, while the upper parts, where the most characteristic of the metasomatic minerals are albite and carbonate, favored concentration of uranium.

The second kind of mineralized zone resembles the first kind in many structural features and in the character of alteration of the enclosing rocks. Its main distinguishing features are considerably stronger silicification and sericitization of the primary rock-forming minerals and, as a rule, the absence of fine-grained second generation sericite. In the zones of the second kind, sericite and quartz completely replace oligoclase phenocrysts and quartz-sericite aggregates are strongly developed in the groundmass. The form of these aggregates suggests orthoclase crystals, orthoclase relicts are occasionally observed, and the quartz phenocrysts are recrystallized. Often the entire rock is an

---

[3]n is an arbitrary index.

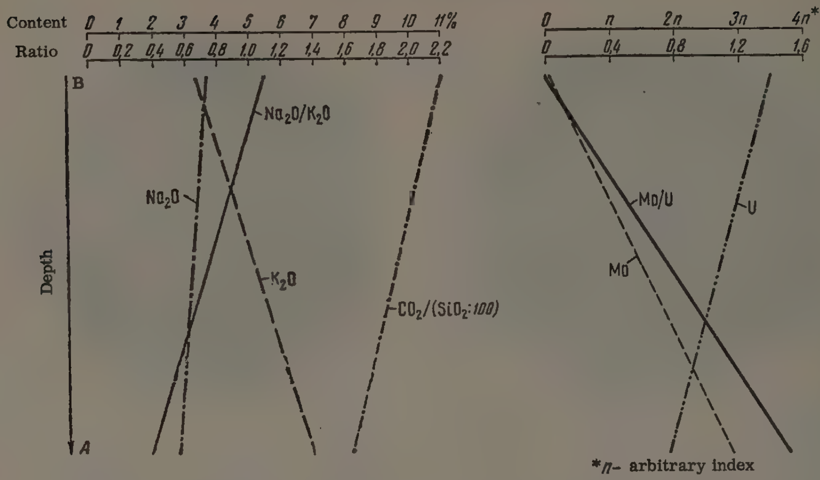

FIGURE 9. Variation curves of petrochemical characteristics and content of molybdenum (Mo) and uranium (U) in the lower (A) and upper (B) parts of mineralized zones of the first kind.

aggregate of sericite and fine-grained quartz with segregations of ore minerals, small patches of carbonate and occasional ghosts of quartz phenocrysts represented by recrystallized quartz. The amount of quartz reaches 40 to 50% and of sericite, 50 to 70%.

The decrease in the Na_2O/K_2O ratio from 017 to 0.5 in the fresh rocks to 0.005 in the altered ones is much sharper than in the zones of the first kind, and the same is true of the decrease in sodium content from 3.4 to 0.15 and of potassium from 6.0 to 1.9%. The latter change is explained by intensive replacement of oligoclase by sericite and the replacement of orthoclase phenocrysts by quartz-sericite aggregates with partial removal of potassium according to the reaction:

$$3KAlSi_3O_8 + H_2O + CO_2 \rightarrow$$

$$KAl_3Si_3O_{10}(OH)_2 + 6SiO_2 + K_2CO_3$$

In the upper parts of the mineralized zones and several meters above the place where they wedge out in the metasomatized rock, orthoclase is replaced by albite, and carbonate is present. The oligoclase phenocrysts are replaced by sericite and in part by carbonate and quartz. The microscope shows that pitchblende most frequently occurs in the upper parts of the zones and molybdenite in the intermediate and, less frequently, in the lower and upper parts.

These observations are confirmed by chemical analyses, which show that in passing from the sericitized and silicified rocks to the albitized and carbonatized rocks, the Mo/U ratio increases in the transitional zone and then rapidly decreases.

To check this, a number of areas in the zones of the second kind, in which the transition from the sericitized and silicified rock to albitized and carbonatized was well exposed, were studied in detail. A description of one of the more typical areas is given below.

It was established by a detailed study of thin sections from this area that samples 1, 2, and 3 are characterized by an intensive replacement of oligoclase by sericite and slight replacement by carbonate and quartz and also by development of quartz-sericite aggregates. In a few thin sections relicts of strongly kaolinized orthoclase were found.

Upwards along the zone, in the altered rocks (spp. 4, 5, 6, 7, 8, and 9), there is a noticeable increase in carbonate and especially in albite. In some areas, checkerboard albite constitutes up to 60-80% of the total volume of the rock, and in such cases almost entirely replaces the phenocrysts. Evidently albite completely replaces orthoclase and oligoclase. Albite occasionally develops along the periphery of recrystallized quartz grains. Besides albite and carbonate, fine-grained sericite and secondary quartz are found.

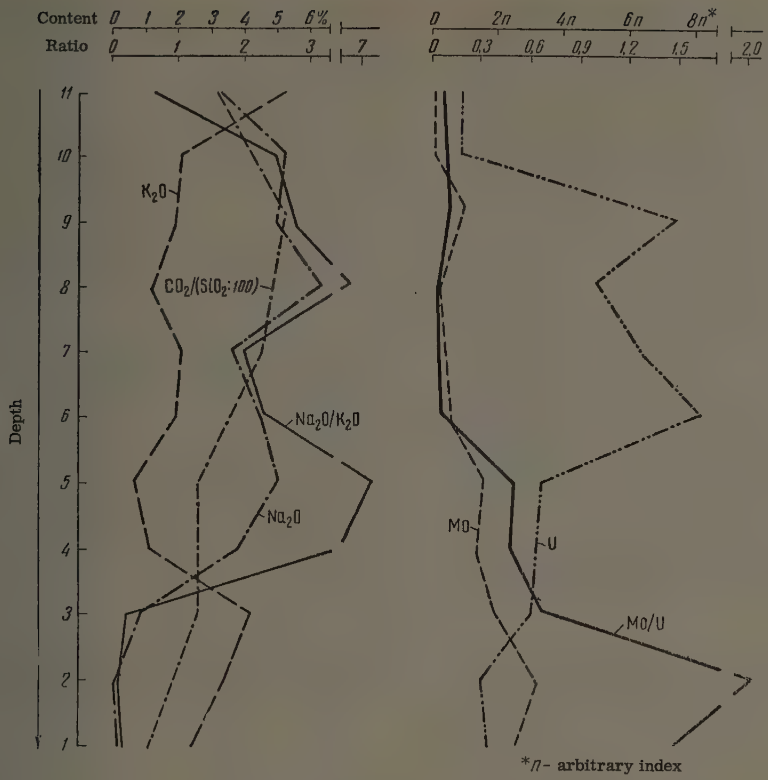

FIGURE 10. Variation curves of petrochemical characteristics and content of molybdenum (Mo) and uranium (U) in passing from the lower sericitized and silicified areas to albitized and carbonatized areas in the zones of the second kind.

In the upper parts of these areas (spp. 10 and 11), where the intensity of rock alteration is considerably less, the orthoclase is only occasionally replaced by checkerboard albite, and oligoclase by sericite, carbonate and sometimes quartz and chlorite.

Molybdenite and pitchblende in these areas are found as included grains and microscopic segregations in the aggregates of sericite, quartz, carbonate, less commonly, chlorite, and also in the clusters of albite and carbonate grains.

The relationship between petrochemical characteristics and the content of molybdenum and uranium is illustrated by graphs (Fig. 10) constructed on the basis of chemical analyses. They show that the highest molybdenum content (1.5n to 3.5n) is found in those areas of the mineralized zones in which the Na_2O/K_2O and $CO_2/(SiO_2:100)$ ratios increase from 0.2 to 1.1 and 0.4 to 1.5, respectively. The values 0.2 and 0.5 for these ratios are characteristic of the sericitized and silicified rocks and the values 1.1 - 7.0 and 1.5, of the albitized and carbonatized rocks. These areas, therefore, are transitional between the sericitized and silicified and the albitized and carbonatized rocks.

Upwards in the zone in the interval where the Na_2O/K_2O ratio varies from 2.0 to 7.0 and the $CO_2/(SiO_2:100)$ ratio, from 1.5 to 2.5, the molybdenum content decreases to 1.0 - 0.1n and the uranium content increases to 3 - 8n. Although the peaks of the curves representing these ratios and of the curves of uranium content do not coincide, nevertheless the localization of the high uranium content in

in the areas with the higher Na_2O/K_2O and $CO_2(SiO_2:100)$ ratios and the higher Na content is evident.

Where the mineralized zones wedge out there is a considerable decrease in the Na_2O/K_2O ratio, a slight decrease in the $CO_2/SiO_2:100)$ ratio, and a sharp decrease in uranium content. However, just as in the areas of intensive albitization and carbonatization, the uranium content remains higher than the molybdenum content.

That the uranium content increases and the molybdenum content decreases with increase in the Na_2O/K_2O ratio was confirmed by study of the mineralized zones of the third kind.

In zones of the third kind the general character of alteration is similar in the upper and lower parts. Orthoclase is replaced by checkerboard albite, and carbonate occurs in subordinate amounts. Sericite and carbonate, and occasionally quartz, replace oligoclase, and in the upper parts of the zones albite joins these minerals. It was found that albite is more common in the upper than in the lower parts, while carbonate, sericite and quartz are approximately equally developed in both.

The chemical analyses (Fig. 11) shows that the Na_2O/K_2O ratio increases upwards from 1.0 to 1.4, due, as has already been mentioned, to a greater development of albite in the upper part of the zones as compared with the lower. There is no noticeable variation in the $CO_2/(SiO_2:100)$ ratio.

As the Na_2O/K_2O ratio increases, the content of molybdenum decreases from 0.7n to 0.5n, and that of uranium increases, from 0.6n to 4.5n; in other words, there is a sharp decrease in the Mo/U ratio.

All this indicates that, as the process of albitization becomes more intensive, conditions for accumulation of uranium become more favorable.

Thus, our observations show, first, that molybdenum is concentrated in the sericitized and silicified areas in which second generation sericite develops simultaneously with the metasomatic sericite replacing oligoclase and, second, that molybdenum accumulates in the zone of transition from the sericitized and silicified rocks to the albitized and carbonatized rocks, or, in other words, to the lower parts of the areas of albitized and carbonatized rocks where checkerboard albite replacing orthoclase is found.

As for uranium, its highest content is localized mainly in the areas of intensive albitization and carbonatization. The regular increase in uranium content from the lower parts of the zones to a certain maximum,

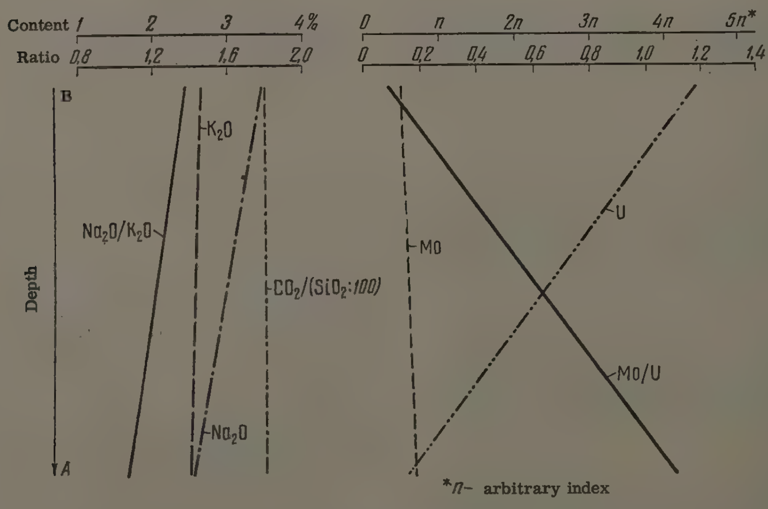

FIGURE 11. Variation curves of petrochemical characteristics and molybdenum (Mo) and uranium (U) content in the lower (A) and upper (B) parts of mineralized zones of the third kind.

followed by a decrease, reflects the optimum conditions for the deposition of uranium oxides from hydrothermal solutions.

A brief discussion of the chemistry of the processes responsible for the mineralized zones and for the distribution of the minerals in them is given below.

The common occurrence in the parageneses with the ore minerals of vein and metasomatic calcite, checkerboard albite, and two generations of sericite suggests that the solutions contained carbonic acid and a certain concentration of sodium and potassium ions. The presence of the sulfides in these parageneses and occasional appearance of fluorite indicate that the solutions contained sulfur ions and a small amount of fluorine.

It is known [5] that in alkaline solutions, molybdenum forms easily soluble salts of molybdic acid. In the presence of sulfur in the solutions (of hydrogen sulfide or its solutions) the oxygen in the anion of molybdic acid will be replaced by sulfur and thio salts will form. This will not make any noticeable change in the solubility of the molybdenum compounds. One of the products of decomposition of the thio salts is MoS_3, which, on losing one atom of sulfur, changes into the practically insoluble sulfide, molybdenite — MoS_2. The molybdenum compounds and complexes in which it occurs in lower oxidation states have been little studied.

The presence of tungsten in molybdenite is easily explained, for, belonging to the same subgroup of the periodic table, these two elements have similar properties and form salts soluble under similar conditions. The explanation of the presence of rhenium in molybdenite must also be sought in its position in the periodic table.

It is well known that in Mendeleev's table [6] the basicity of the elements decreases from the first group to the last (excluding the noble gases) and increases within each subgroup with the atomic weight of the element; therefore, in many cases, the elements lying along the diagonals may form salts with similar properties. This is the reason why molybdenum and rhenium form salts soluble under similar conditions. An example of this is the existence of rhenium, potassium and sodium thio salts similar to those of molybdenum which, upon decomposition and removal of a part of the sulfur, yield rhenium sulfide. It may be assumed, then, that rhenium enters into the molybdenite lattice, not only because it has an ionic radius similar to that of molybdenum, but also because it can enter into it in the form of finely dispersed rhenium sulfide which cannot be detected at the highest optical magnifications.

Uranium is probably carried in these solutions in complex compounds. These compounds may be similar to those known in chemistry in which uranium enters into complex carbonate, fluocarbonate and other anions. The salts with these complex anions, especially those of sodium and potassium, are relatively easily soluble and decompose with separation of metal oxides and carbonic acid.

The presence in the pitchblende of traces of scandium, zirconium, thorium and niobium is explained by the fact that these elements migrated under the same conditions as uranium, in carbonate and fluocarbonate complexes containing alkali metals.

Iron, lead, zinc and copper, which occur in pyrite, galena, sphalerite and chalcopyrite, respectively, might have been present in the solutions as complex compounds. It is possible that silver, tin, arsenic, antimony and bismuth, occurring in traces in different minerals [1, 8, 9, 10, 12], also were present in this form.

Calcium and barium, considering their basicity and the solubility of their compounds, might have been present in the solutions as simple cations.

The presence of the same minerals in the mineralized zones suggests that the solutions responsible for the mineralization contained the same ions. However, judging by the sharp differences in the proportion of these minerals in the zones, and the character of alteration of the wall rocks, the concentration of these ions in the hydrothermal solutions varied and was substantially different from their concentration in the pore solutions of the enclosing rocks. These circumstances, together with the change in pressure and temperature, as the solutions moved upward in the fractured zones, played a decisive role in varying the character of wall rock alteration and the distribution of elements in the mineralized zones [3, 4]. As was pointed out at the beginning of the paper, these regularities are particularly clear in the case of molybdenum and uranium.

The position of molybdenum and uranium in the periodic table indicates that they have amphoteric properties, and uranium, an element with a larger number of electronic shells than molybdenum, is the more basic of the two. This means that, in an alkaline solution, all other conditions being equal, the acid-forming properties of molybdenum will be stronger than those of uranium.

The strongest bases in the solutions under consideration were the alkali metals, especially potassium, as is indicated by the higher negative value of its electrode potential

(-2.9 v) as compared with that of sodium (-2.7 v).

Without discussing in detail the characteristics of the complex compounds of other elements occurring in the mineralized zones, we shall note that, depending on the solubility and the strength of the anions of these compounds, their behavior in solution was similar to that of the molybdenum or uranium compounds.

Bearing all this in mind, the intensive sericitization of oligoclase and the formation of the second generation sericite may be explained like this. The hydrothermal solutions probably had a rather high concentration of the molybdic acid radical and contained potassium among the other ions. Rising through the fracture zone, they reacted with the pore solutions in the rocks. Naturally, in the pore solutions, especially in the more acid rocks, silica predominated over the ions of the pore elements. In the reaction between the hydrothermal and pore solutions, potassium reacted with silica and was partially removed; i.e., conditions favorable for sericitization of oligoclase were created. A part of potassium could have reacted with the aluminum and silicon salts to form second generation sericite.

The fixation of potassium caused destruction of molybdenum compounds and precipitation of molybdenum sulfides. The enrichment of the solutions in sulfur favored deposition of the pyrite abundant in the parageneses with molybdenum and also of small amounts of galena, sphalerite and other sulfides. The reaction was probably like this [11]:

$$K_2MoS_4 + FeO + H_2O \rightarrow MoS_2 + FeS_2 + 2KOH.$$

It should be mentioned that the decomposition of molybdenum thio salts, accompanied by the reduction of Mo^{6+} to Mo^{4+}, must have contributed to the solutions, not only the sulfide ion, but also the sulfate ion and neutral sulfur. The presence of barite is a direct proof of the presence in the solutions of the sulfate ion.

All these changes in the hydrothermal solutions and the decrease in pressure with their rise in the fractured zones caused further precipitation of molybdenum sulfides and the destruction of uranium complexes.

The decomposition of the sodium uranium carbonates, together with the coagulation of the uranium oxides, increased the concentration of sodium in the solutions. Moreover, with the destruction of the complexes of other metals, and in particular of iron and molybdenum, the solutions became enriched in hydrogen sulfide, sulfate and hydrogen halides. The increased content of strong acid radicals in the solutions caused the removal of alkali metals, especially of potassium, and created favorable conditions for the replacement of potassium by sodium in the feldspars and, in particular, for the development of metasomatic checkerboard albite at the expense of orthoclase. It is possible that reactions of the following type also took place:

$$2KAlSi_3O_8 + 2NaOH + Ca(HCN) \rightarrow$$
$$2NaAlSi_3O_8 + CaCO_3 + 2H_2O + K_2CO_3.$$

Such reactions would explain to some extent the observed paragenesis of albite and calcite in the replacements of orthoclase. In those areas where the concentration of the reactive sodium was high, the checkerboard albite replaced oligoclase as well [7].

Calcium and barium ions also reacted with the carbonate, sulfate and hydrogen halide ions, forming calcite, occasional fluorite and barite, which are practically insoluble under the given conditions. The soluble salts of calcium, sodium and potassium were removed.

As has already been mentioned, these processes were accompanied by the precipitation of sulfides, among which pyrite and galena were the most abundant. Synchronously with the deposition of molybdenum sulfides, uranium oxides and other minerals, the trace elements occurring in these minerals were also precipitated.

The formation of the quartz-sericite aggregates in the lower parts of the zones of the second kind, and the rather intensive removal of many elements and especially of the alkalis and alkaline earths, were due, apparently, to the fact that in the initial stages of alteration the hydrothermal solutions were poorer in these metals than the pore solutions.

The change in pressure also played a certain role. The decrease in pressure in the fractured zones caused the destruction of a number of complex compounds, including those of uranium, and the coagulation of uranium oxides and different sulfides.

As the hydrothermal solutions rose in the fractured zones, further decomposition of the complex uranium salts occurred, increasing the amount of uranium oxides as compared with molybdenum sulfides. Paralleling these processes in the upper parts of the mineralized zones, as has already been explained in the description of zones of the first kind, the feldspars were albitized and ore and vein minerals were deposited.

The development of albite throughout the mineralized zones of the third kind may evidently be ascribed to the relatively high

concentration of sodium ions in the solutions at the time they entered the fractured zones. Evidently there was a sharp pressure decrease and this caused an intensive destruction of the complex compounds in the initial stages of mineral deposition. All this aided in the development of the processes of alteration and mineral deposition analogous to those already described for the areas of albitized rock in the upper parts of the mineralized zones of the first and second kinds.

The hydrothermal solutions as described here are undoubtedly far simpler than the complex natural solutions, yet apparently resemble them in a general way. This is confirmed by the fact that hypothetical solutions are such that all the essential and trace elements of the minerals in the mineralized zones could have migrated in them and by the fact that the chemistry of the processes responsible for wall rock alteration and mineral deposition as outlined here reveals a connection among these processes and explains the distribution of the minerals in the zones. To do this in all possible detail for molybdenum and uranium was the object of this paper.

REFERENCES

1. Betekhtin, A.G., GIDROTERMAL'NYYE RASTVORY, IKH PRIRODA I PROTESSY RUDOOBRAZOVANIYA. V KN. OSNOVNYYE PROBLEMY V UCHENII O MAGMATOGENNYKH RUDNYKH MESTOROZHDENIYAKH [HYDROTHERMAL SOLUTIONS, THEIR NATURE AND THE PROCESSES OF ORE FORMATION. IN THE BOOK: FUNDAMENTAL PROBLEMS IN THE STUDY OF MAGMATIC ORE DEPOSITS]: Izd. Akademiya Nauk SSSR, 1955.

2. ___________, PONYATIYE O PARAGENEZISE MINERALOV [THE CONCEPT OF MINERAL PARAGENESIS]: Izvestiya, Akademiya Nauk SSSR, ser. geol, no. 2, 1949.

3. Korzhinskiy, D.S., OCHERK METASOMATICHESKIKH PROTSESSOV. V KN. OSNOVNYYE PROBLEMY V UCHENII O MAGMATOGENNYKH RUDNYKH MESTOROZHDENIYAKH [METASOMATIC PROCESSES. IN THE BOOK: FUNDAMENTAL PROBLEMS IN THE STUDY OF MAGMATIC ORE DEPOSITS]: Akademiya Nauk SSSR, 1955.

4. ___________, ZAVISIMOST' AKTIVNOSTI KOMPONENTOV OT KISLOTNOSTI RASTVORA I POSLEDOVATEL'NOST' REAKTSIY PRI POSLEMAGMATICHESKIKH PROTSESSAKH [DEPENDENCE OF THE ACTIVITY OF COMPONENTS ON THE ACIDITY OF THE SOLUTION AND THE SEQUENCE OF REACTIONS IN POSTMAGMATIC PROCESSES]: Geokhimiya, no. 7, 1956.

5. Nekrasov, B.V., KURS OBSHCHEY KHIMII [COURSE OF GENERAL CHEMISTRY]: Gostekhizdat, 1952.

6. Mendeleev, D.I., OSNOVY KHIMII, T 2 [PRINCIPLES OF CHEMISTRY, V. 2]: Gostekhizdat, 1934.

7. Rekharskiy, V.I., NEKOTORYYE OSOBENNOSTI OBRAZOVANIYA AL'BITA V OKOLOZHIL'NYKH OREOLAKH [CERTAIN CHARACTERISTICS OF FORMATION OF ALBITE IN NEAR-VEIN AUREOLES]: Doklady, Akademiya Nauk SSSR, t. 118, no. 4, 1958.

8. Saukov, A.A., GEOKHIMIYA RTUTI [GEOCHEMISTRY OF MERCURY]: Tr. In-ta geol. nauk Akademiya Nauk SSSR, vyp. 78, 1946.

9. SPRAVOCHNIK KHIMIKA [HANDBOOK OF CHEMISTRY]: t. 2. Goskhimizdat, 1952.

10. Strelkin, M.F., K VOPROSU OB OLOVONOSNYKH PEGAMTITAKH [ON TIN-BEARING PEGMATITES]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 3, 1958.

11. Shcherbina, V.V., FORMY PERENOSA KHIMICHESKIKH ELEMENTOV V PROTSESSE MINERALOOBRAZOVANIYA I USLOVIYA IKH KONTSENTRATSII. V KN. VOPROSY GEOKHIMII I MINERALOGII [THE MODE OF TRANSFER OF THE ELEMENTS DURING THE PROCESS OF MINERAL FORMATION AND THE CONDITIONS OF THEIR CONCENTRATION. IN THE BOOK: PROBLEMS OF GEOCHEMISTRY AND MINERALOGY]: Akademiya Nauk SSSR, 1956.

12. Becker, G. F., GEOLOGY OF QUICKSILVER DEPOSITS OF THE PACIFIC SLOPE: Govt. Printing Office, Washington, 1888.

13. Kidd, D.F. and M.H. Haycock, MINERAGRAPHY OF THE ORES OF GREAT BEAR LAKE: Bull. Geol. Soc. America, no. 6, vol. 46, 1945.

14. Stevenson, F.S., URANIUM MINERALIZATION IN BRITISH COLUMBIA: Econ. Geol., no. 4, vol. 46, 1951.

15. Thoreau, J. and R. DuTrieu de Terdonck, LE GITE D'URANIUM DE SHINKOLOBWE -KASOLO (KATANGA): Bruxelles, 1933.

THE ORIGIN OF THE ARCHEAN IRON ORES OF SOUTH YAKUTIYA[1]

by

D. P. Serdyuchenko

One of the important geological events of the last decade was the discovery and detailed study of the iron basin in the Archean metamorphics of South Yakutiya. The ancient schists, derived from sediments which contain the magnetite deposits, lie in the zone of later granitic intrusions associated with extensive migmatization. The iron ores of South Yakutiya are locally accompanied by boron (silicates and borates) or rare earth minerals, by deposits of phlogopite and other useful minerals and are of great scientific interest.

The principal geologic characteristics of the South Yakutian Archean iron deposits are given below:

a) The magnetite ores are associated with a metasedimentary complex composed of biotite-garnet, biotite-graphite and cordierite gneisses, dolomitic marbles and calciphyres, pyroxene-amphibole-plagioclase and pyroxene-amphibole-scapolite schists and gneisses, and various quartzitic gneisses and quartzites including hematite, sillimanite, sillimanite-tourmaline, tourmaline and other varieties.

b) The ores are restricted to a definite stratigraphic horizon — the Archean Fedorovskaya formation of the Iyengra series of the Aldan shield. The productive horizon extends for many tens of kilometers along the strike. In depth, down dip, the ores have already been traced for almost one kilometer without showing any signs of wedging out. In a number of cases the iron ores occur in the cores of synclines.

c) After the deposition of ore, faults, fracture zones and granitic intrusions cut through the rocks of the Fedorovskaya formation and through the overlying Timpton and Dzheltula series.

d) There are concordant and often zoned skarn-like bodies produced by reaction metasomatism between metasediments of different composition. Granitic intrusions and their derivatives, and hydrothermal activity, have also contributed to local skarn formation and to the development of metasomatic zonation concordantly superimposed upon the paraschist series (including the ore-bearing beds). The differences in the composition of the paraschists mainly reflect the original differences in composition of the parent sedimentary rocks rather than a secondary metasomatic zonation developed on the carbonate and silicate rocks.

e) The iron ores and the associated boron-bearing rocks, tourmaline gneisses and schists, are concordant with the enclosing paraschists and, together with them, participate in the folded structures, interbedding repeatedly with the barren beds and layers of different composition, themselves containing various gangue minerals characteristic of the enclosing beds.

f) The ore minerals (magnetite and the less abundant hematite), the boron minerals (ludwigite, ascharite, tourmaline), and almost all other minerals from the rocks of the productive horizon (spinel, phlogopite, chondrodite-clinohumite, scapolites, pyroxenes, amphiboles and others) are represented by several generations reflecting the different stages and conditions of formation and alteration of the rocks (regional metamorphism of ancient sediments, reaction and infiltration metasomatic phenomena, later hydrothermal fracture filling, etc.).

g) The ores are usually finely or coarsely banded, equigranular or with microscopic spots, frequently microfoliated (Figs. 1, 2, 3, 4, 5) and structurally and texturally similar to the majority of Precambrian metasedimentary ores.

It is natural that the Archean iron ore deposits of South Yakutiya, of a type and mineralogical composition previously unknown in the U.S.S.R., should have attracted much attention. Their origin, in particular, has

[1] Proiskhozhdeniye arkheyskikh zheleznykh rud yuzhnoy yakutii.

been a subject of investigation, for it is well known that such investigations have considerable practical importance in the prognosis of new deposits, direction of prospecting and exploration, and evaluation of reserves, of the reliability of deposits, etc.

Of course, the basis for the correct solution of genetic problems must be a thorough and objective gathering of geological data, first on this particular ore-bearing region, then on other ancient iron-bearing provinces.

However, in his article, "The genesis of the South Yakutian iron ore deposits," L.I. Shabynin [30], while declaring his desire "to correct a number of serious inaccuracies in the description of these deposits (South Yakutian D.C.) which have, unfortunately, appeared in some of the published works," gave such an incorrect description of the main geological features of the South Yakutian iron basin that his paper, instead of bringing the reader into the actual geological setting of the area, removes him from it.

The detailed drilling in the Fedorovskaya formation of the Taezhno-Legliyerskiy ore belt shows that the magnetite ores of the productive horizon are conformably overlain by a series of sillimanite, cordierite-sillimanite, tourmaline-sillimanite and tourmaline quartzites and gneissoid quartzites which preserves in its upper part conformable beds of hematite quartzites (at the Gematitovoe deposit). The Fedorovskaya formation is underlain by the Nemnyr formation, which on the Malyi Nemnyr River and elsewhere contains biotite-magnetite and biotite-magnetite-sillimanite-cordierite, pyroxene-amphibole-plagioclase gneisses and schists). Further down in the section is the Verkhnealdansk formation characterized by the predominance of various quartzites containing groups of beds and individual beds of coarse-grained magnetite quartzites and even finely laminated quartz-magnetite hornfelses ("jaspilites"). It is remarkable that the magnetite quartzites pass gradually (on the Iyengra, Malyi Nemnyr, Amedichi and other rivers) into magnetite-quartz-hornblende and magnetite-hornblende

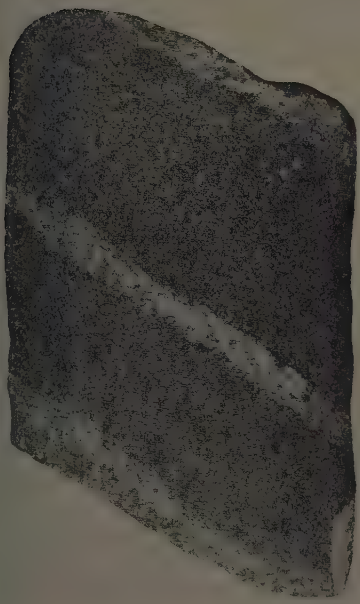

FIGURE 1. Banded (foliated) magnetite-serpentine-phlogopite ore.

Sp. G-434/56; Tayezhnoye deposit; actual size. Phlogopite forms anchimonomineralic bands (light).

FIGURE 2. Banded phlogopite-serpentine-magnetite ore.

Sp. C-275/52; Tayezhnoye deposit; polished section; magnetite -- light gray; actual size.

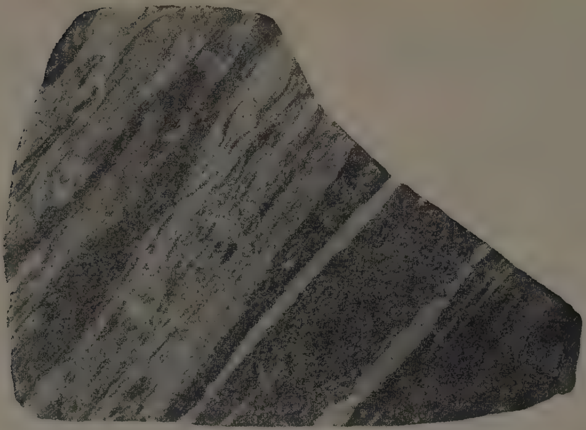

FIGURE 3. Thinly banded magnetite-scapolite-diopside ore with several generations of sulfides.

Sp. P-72/56, Pionerskoye deposit; polished section; actual size.

FIGURE 4. Plagioclase-diopside-hornblende rock with magnetite, quartz and biotite alternating in thin bands with scapolite-plagioclase rock (light).
Polished section; actual size; sp. 138/56. Pionerskoye deposit.

FIGURE 5. Thinly banded magnetite-diopside-amphibole ore with allanite.

Sp. P-7/256. Pionerskoye deposit; polished section; actual size.

schists, either massive and equigranular or with irregular and octahedral magnetite porphyroblasts or alternating thin bands of quartz, hornblende and magnetite. These schists lie conformably on biotite-garnet gneisses, sillimanite and graphite schists and quartzites [3, 12, 31].

Thus, there are within the Iyengra series three ore-bearing zones: the middle magnetite-silicate zone, the upper hematite-quartz zone, and the lower magnetite- (or hematite-) zone. The magnetite and hematite quartzites so characteristic of the world's Precambrian formations are quite correctly regarded by all geologists as metamorphosed sedimentary rocks. D.S. Korzhinskiy [6] believes that the magnetite quartzites of South Yakutiya are also of this origin. It is natural to conclude that, during the time of deposition of the ancient sediments of the Iyengra series in the Aldan region, iron was accumulated repeatedly in different facies. After a period of metamorphism and granitic injections these accumulations acquired the composition which they now have, i.e., magnetite-silicate rocks and ores in the middle zone and magnetite or hematite quartzites in the lower and upper zones. The contact-metasomatic hypothesis of the origin of iron ores of the productive horizon assumes, for no convincing geological reason, that the magnetite-silicate ores, in contradistinction (!?) to the overlying and underlying groups of metasedimentary magnetite gneisses, magnetite-quartz amphibolites and magnetite and hematite quartzites, received their iron from a granitic magma. This magma, however, proved to be completely barren in relation to the overlying Timpton and Dzheltula series, which, like the productive horizon, contain beds of dolomite and calciphyre and are intruded and migmatized by the same granites. The concept of selective enrichment in iron (and boron), affecting the productive horizon of the Fedorovskaya formation only, appears quite incomprehensible and has no basis in light of the magmatic theory of ore deposition.

In discussing the age of the iron ores of South Yakutiya, L.I. Shabynin [30] also distinguishes three ore-bearing zones, but in an entirely different way. His zones are: a) the Fedorovskaya formation of the Archean Iyengra series, which contains all the principal economic deposits (Nerichi and Dess, Sivagli, Pionerskoye and Komsomol'skoye, Tayezhnoye, Magnitovoye, Legliyerskoye and the Tinskiye deposits); b) the Archean Dzheltula series (upper), to which he assigns, referring to the unpublished data of M.A. Litsarev,[2] the Emeldzhak group of magnetite and phlogopite deposits; and c) the central Aldan deposits localized in the contact of Mesozoic syenite porphyries with Cambrian dolomites.

Disregarding for the moment the Central Aldan group of deposits belonging to the upper structural level, we must recall [17, 18] that the iron ore and micaceous rocks of the Tayezhnoye, Legliyerskoye and Emel'dzhak deposits are exactly of the same type and hence can be correlated and referred to the same stratigraphic (productive) horizon of the Fedorovskaya formation. Although the Archean rocks have a general monoclinal plunge (cf. [4]) to the northeast, the outcroppings of productive beds in the region of the Emel'dzhak River were produced by erosion of the northwest trending anticlinal folds whose cores contain the productive beds of the Fedorovskaya formation.

This point of view was fully confirmed by the recent (1956-1958) mapping by the geologists of the South Yakutian Complex Expedition of the Ministry of Geology U.S.S.R. [13], which showed unequivocally that the Emel'dzhak ore deposits (like the rest of the Archean deposits of this type) lie in the productive zone of the Fedorovskaya formation and that Shabynin's data on which he bases his assignment of the Emel'dzhak ores to the Dzheltula series are erroneous.

In discussing the relationship between the ores and granites in the South Yakutian deposits, Shabynin ([30], p. 46) declares that "No one ever found granitic injections in the apodolomitic, in part essentially olivine (serpentine), skarns and ores." This assertion does not correspond to reality.

In the northeastern and southeastern areas of the syncline, at the Taezhnoye deposit, the ore-bearing beds (including those containing forsterite, chondrodite and serpentine) are so thoroughly injected with granitic material and migmatized in the east that they appear in their original state only as interrupted bands and separate large and small remnants (xenoliths) of ore bodies and country rock in a body of granite. The intrusion of granites into the ore-bearing strata caused formation of skarn (andradite, aegirine-augite and others) and local transfer of large amounts of iron, calcium and magnesium into the

[2] It is interesting to note in this connection that in a recently published work, M.A. Litsarev [10] assigns the ore-bearing Emel'dzhak complex to the Dzheltula series on the basis of a "private communication" from L.I. Shabynin, who finds outward resemblance between the andradite-wollastonite rocks in the region of Emel'dzhak and the andradite wollastonite rocks of the Timpton River, which he refers to the Dzheltula formation.

enclosing gneisses and schists with the formation along their foliation planes and in the joints ahead of the front of migmatization of irregular metasomatic ore bodies composed essentially of magnetite, diopside, blue-green hornblende and phlogopite and containing occasional relicts of the replaced gneisses and schists.

At the Legliherskoe deposit (near the source of the Legliyer River), pink granite not only intrudes the ore-bearing beds but surrounds whole areas of the enclosing diopside-plagioclase gneisses, together with magnetite-phlogopite and magnetite-hornblende ores, and these xenoliths retain their banding and foliation. Near the contact with rich ore, the granite contains pods and bands of magnetite (fused and recrystallized) which parallel the strike of the ore-bearing beds, and also small inclusions of magnetite-hornblende aggregate.

At the Sivagli deposit, where pink granite intrudes the magnetite ores of the southern area (ore body III), the thickness of the ore diminishes sharply (from 30 to 12 m); i.e., it is "swallowed" by granite and at the contact with granite magnetite is recrystallized into larger grains ranging from 5 to 7 mm in diameter, while the granite itself is irregularly (but locally abundantly) enriched in subrounded irregular or flattened grains and aggregates of magnetite and in small inclusions of magnetite obviously extracted from the enclosing rocks. The magnetite rapidly disappears from the granite with increasing distance from the intruded rocks.

In the northern part of the same deposit (Sivagli, holes 30, 86 and others), as a result of numerous intrusions of granite, the ore-bearing beds have been changed to fine-grained andradite-epidote-magnetite or andradite-actinolite-magnetite skarn formed at the expense of hornblende and diopside-hornblende rocks. Near these areas (hole 57-C and others), in the zone of intensively migmatized gneisses, there are small aggregates of magnetite or zones of pyroxene-amphibole and pyroxene-magnetite rocks. They lie concordantly with the foliation of the gneisses, fill fractures and occur as veins and tubular bodies obviously replacing the gneisses. The phenomenon of iron-magnesium-calcium metasomatism here and at the Tayezhnoe deposit is related to the transfer of material from the nearby pyroxene-amphibole-magnetite ores.

On the Nerichi River, in the southern part of exploratory trench No. 12, among hornblende and biotite gneisses and paraschists (locally injected with granite) there are rather thick and concordant banded and schistose beds of diopside-magnetite ores and rocks. In the cleaned parts of the trench it can be seen quite clearly that over large areas the ore-bearing beds are cut obliquely, across the schistosity, by pink medium- and coarse-grained granites. The magnetite zone is penetrated by tongues and anastomosing veins of granite forming a network of irregularly alternating areas of ore and granite. Blocks of ore and country rock occur in granite as partly assimilated xenoliths.

In the southern part of the Pionerskoye deposit, where the bedded structure of the ore-bearing rocks is very well preserved, the ore body thins out sharply in the zone of granitic intrusions (it is "swallowed" by granite). Here also (hole 57-P and others) the cores (from V.A. Pavlov's collection) show clearly concordant and transgressive injections of thin veinlets of pink granite into the dark-gray diopside-magnetite ore.

These facts show that Shabynin's assertions are unfounded. In order to support the contact-metasomatic hypothesis which he accepts, he tries to show that no ore bodies existed before the intrusion of granites, that the granites were intruded into barren rocks and enriched them metasomatically in iron derived from the granite magma and its pneumatolytic and hydrothermal derivatives.

Referring to the data on the Pionerskoye (hole 57-P) and Sivagli (holes 38-C and 40C) deposits, V.A. Pervago, L.M. Minkin and V.F. Kozlov, geologists of the South Yakutian Expedition (1957), also point out the incorrectness of Shabynin's assertion that there are no granitic intrusions in the ore bodies and the enclosing rocks and stress the fact that granites were intruded into already existing ore bodies.

Quite incorrect and contradictory to the facts is Shabynin's thesis ([30], p. 50) that there is "a clear-cut relationship between structural elements and mineralization." He considers the Pionerskoye deposit as the best illustration of this. According to him, "It lies in the zone of considerable pre-ore deformation. Here magnetite replaces strongly brecciated near-skarn diopside-scapolite rocks. The ore mineral is absent from the fragments. . . . The attempts to interpret the ores of the Pionerskoye deposit as having sedimentary-metamorphic origin [17, 18] must be considered groundless. . . ." So writes Shabynin, but actually there is no genetic relationship between mineralization and the fracture zones in the Pionerskoye or any other deposit. The samples of breccia from the Pionerskoye deposit in our possession (Fig. 6) contain numerous fragments of typical magnetite ore, diopside-hornblende-scapolite rock and migmatite; i.e., the tectonic movements here came after the deposition of the ore, and both the ore and the country rock

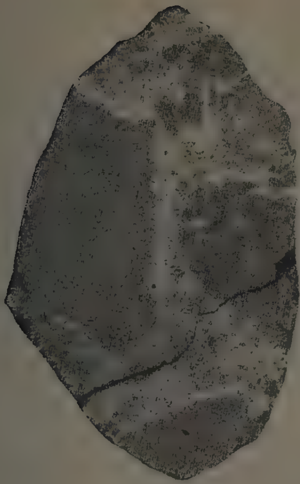

FIGURE 6. Post-ore tectonic breccia with large and small fragments of magnetite-diopside ore cemented by calcite and dolomite.

Pionerskoye deposit; actual size.

were brecciated. Shabynin missed this very important point and in his description drew geological conclusions which are as broad as they are fallacious. Pervago, Minkin, Kozlov and others also point out the post-ore nature of deformation and refute Shabynin's opinion.

Further, the same author believes that an important argument in favor of the contact-metasomatic origin of the South Yakutian Archean deposits is their "well developed" metasomatic zoning.

Numerous sections (Fig. 7) constructed on

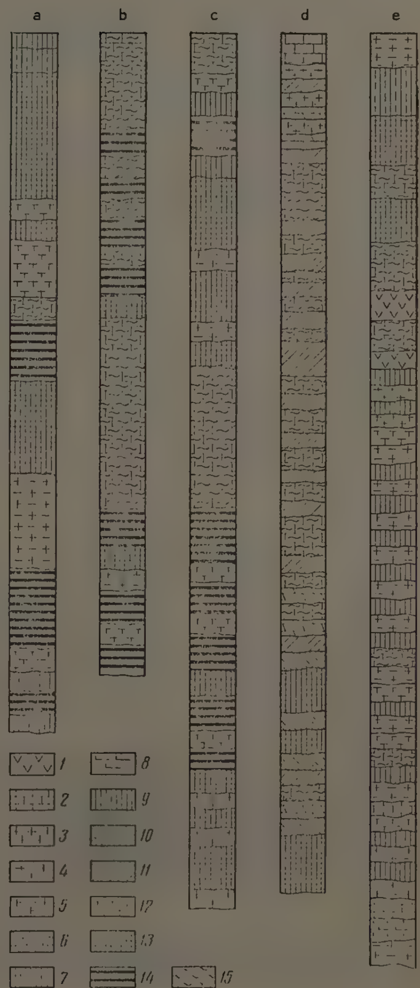

FIGURE 7. Simplified lithologic sections of the iron deposits of South Yakutiya.

1 -- Upper Jurassic syenite porphyries;
2 -- Cambrian dolomites and dolomitized limestones;
3 -- alaskites, granite pegmatites and pegmatites;
4 -- migmatites;
5 -- biotite (commonly with graphite), biotite-hornblende and hornblende (locally with diopside) paragneisses and paraschists, frequently granitized;
6 -- pyroxene-scapolite-garnet skarns;
7 -- recrystallized (pegmatoidal) and locally metasomatized biotite, biotite-hornblende and hornblende (with diopside) gneisses and schists;
8 -- sillimanite (locally with tourmaline) quartzites, gneissoid quartzites and gneisses;
9 -- diopside, diopside-phlogopite, diopside-phlogopite-hornblende rocks (locally with tourmaline, serendibite, spinel and magnetite), phlogopite rocks and serpentinites;
10 -- diopside-scapolite schists (locally with an amphibole);
11 -- diopside-scapolite schists;
12 -- tourmaline-diopside-plagioclase schists and tourmaline rocks;
13 -- magnetite-silicate ores (with forsterite, diopside, and serpentine; serpentine and phlogopite; hornblende and scapolite);
14 -- magnetite ores with chondrodite or clinohumite, serpentine, pyrrhotite and other minerals;
15 -- calciphyres and dolomitic marbles;

a - e -- sections from different boreholes.

the basis of cores from the drillholes show that the complex frequent alternation of layers, beds and groups of beds differing in mineralogy does not fit any definite "metasomatic column" such as is usually observed in many deposits at contacts between dolomites and granite. Between the dolomites (calciphyres) and the aluminosilicate rocks (gneisses) there are frequently forsterite-diopside, phlogopite, pyroxene-amphibole, scapolite-diopside and other rocks whose sequence and repetition are quite unlike metasomatic zoning and must be interpreted as banding of sedimentary-metamorphic origin complicated by reaction metasomatic zones formed between dolomitic, magnesium-silicate, magnesium-lime-silicate and aluminosilicate rocks. In many cases biotite-graphite paragneisses interbed repeatedly with diopside-amphibole-phlogopite schists, diopside-plagioclase-tourmaline schists, and magnetite ores locally containing admixtures of magnesium-iron-calcium silicates or magnesium-iron borates.

It has been known for a long time that metamorphism of siliceous dolomites produces almost monomineralic diopside rocks and that metamorphism of dolomites containing silica and alumina yields augite-hornblende gneisses.

On the Aldan, besides the scapolite developed after plagioclase, there occurs also a metamorphic scapolite syngenetic with the other essential minerals of the schists, i.e., diopside, hornblende, plagioclase and quartz. In the region of the Pionerskoye, Sivagli and Tinskiye deposits such scapolite schists are widespread and interbed repeatedly with calciphyres, paragneisses and iron ores [19, 20, 21], just as they do in other ancient metasedimentary complexes [8, 16]. The metamorphic origin of scapolite and of scapolite rocks (from sedimentary rocks) in the Aldan region was noted by Korzhinskiy [6, 7], who, like V.K. Kotul'skiy [8], explains the formation of scapolite in the schists, instead of plagioclase, by the high content (excess) of $CaCO_3$ in the parent rocks. In the productive beds of South Yakutiya among the scapolite-plagioclase schists (containing also diopside, hornblende, magnetite and sometimes quartz), thin granitic injections cut the grains of plagioclase, scapolite and other minerals.

Evidently, in order to explain the genesis of scapolite rocks, it is not always necessary to bring in the concepts of metasomatism and magma, as is done by Shabynin. His statement that scapolite rocks occupy a strictly determined position in the cross-sections of ore-bearing strata, is incorrect.

While the thickness of the ore-bearing and barren beds of the productive zone is measurable in meters and tens of meters, the thickness of the reaction-metasomatic zones is only a few centimeters, rarely a few tens of centimeters.

Unfortunately, Shabynin failed to notice that the actual relationship among the rocks of the productive zone reflects clearly the facies changes caused by the difference in the composition of the parent sedimentary rocks, rather than metasomatic changes. Through the entire length of the Tayezhno-Tinskoye (Legliyerskoye) and Sivgali-Dëssa ore belts, one may observe a gradual enrichment of the calciphyres in forsterite, diopside, plagioclase, phlogopite or magnetite occurring as disseminated grains or in layers. In a number of cases the calciphyres, either vertically or along the strike, pass into diopside-plagioclase schists, magnetite-diopside ore, biotite paragneiss, etc.

Ignoring or greatly underestimating the geological relationships which clearly reflect the stratification of the ancient metasediments and the facies changes within them, Shabynin uses in his work an extremely arbitrary and confusing terminology according to which the Archean ore-bearing strata of the Aldan region consist almost entirely of "skarns" or "near-skarn rocks" which he regards, without adequate evidence, as the products of essentially postmagmatic metasomatism accompanied by the addition of Fe, Mg, Si and other elements from the granites.

In reality, as was shown above, these granites were intruded into an already existing ore-bearing sequence which contained magnetite-diopside, magnetite-scapolite, magnetite-amphibole-plagioclase and other rocks, and merely caused further recrystallization and local metasomatic transfer of materials, resulting in the formation of nearly monomineralic magnetite, diopside and scapolite veinlets. The skarns, formed as the direct effect of granitic intrusions, are usually rocks with large and even gigantic crystals of andradite, pyroxene, hornblende, scapolite, actinolite, phlogopite, magnetite and other minerals in various combinations. These rocks were formed as a result of considerable addition (transfer) of material from magma and must be distinguished from the "skarnoids," which are by far more abundant in the ore-bearing strata and were formed in the Aldan region (as in Central Sweden) by recrystallization of sedimentary rocks containing Ca-Mg carbonates, iron, fluorine, phosphorus, boron and other elements under conditions of regional metamorphism without any contributions from magma.

The phlogopite deposits occurring in the same region in the fractures and fracture zones are genetically and spatially related to granitic derivatives and were formed by the introduction of potassium from the magma

(potassium metasomatism), a truly hydrothermal metasomatic process.

The intensive metamorphism and the considerable heating of pore solutions and ground waters caused by it ("pseudohydrothermal solutions") and the later effect of granitic intrusions on the metamorphosed beds resulted in the attainment of equilibrium among the minerals and mineral assemblages and the appearance of reaction metasomatism zones between rocks differing in composition. All this naturally led to the formation in these rocks and zones of definite mineral parageneses. These phenomena, however, resulted from physicochemical ordering of the sedimentary and metasedimentary materials and cannot be used as an argument in favor of "contact-metasomatic" genesis of magnetite or boron mineralization.

It has been known for a long time that the laws of mineral formation and the mineral parageneses in intensively metamorphosed rocks are similar to those in igneous rocks and become identical in palingenesis. For this reason, paragenetic analysis of mineral assemblages cannot help us solve the problem of the origin of Archean iron ores or the boron minerals of the Aldan region, to tell us whether iron and boron are of sedimentary or igneous origin. In this case, the geological setting and the relations among the rocks are of prime importance for the solution of the problem. As was shown above, the granites are younger than the ores and could not have been the source of iron and boron. The barrenness of the granite was noted by N.G. Sudovikov [27]. We cannot, however, agree with his opinion that iron was brought up from great depths, from the region of extensive migmatization of the ancient metasedimentary rocks, for our observations indicate a direct spatial connection between magnetite-diopside-hornblende metasomatites and the beds of iron ore in the metasedimentary strata.

We showed elsewhere [20] that the metamorphism of argillaceous-arenaceous, calcareous, calcareous-ferruginous and carbonate rocks containing a considerable amount of boron of sedimentary origin (chemically precipitated, adsorbed) would produce various boron-bearing metasedimentary rocks corresponding to different metasedimentary facies. Naturally, metamorphism and the accompanying metasomatism took place under conditions of mobility and high concentration of boron, but magma was not its primary source, and those who adhere to this idea have no convincing arguments in its favor. The presence of tourmaline-bearing metasedimentaries suggested that borates may occur in some of their facies in our region, and a study of the distribution of boron in the ore-bearing strata of South Yakutiya was conducted in 1953-1954 (see [18], p. 75, ed. note). The relationship between the tourmaline-bearing rocks and the discovered borate beds is that between different facies of the metasedimentary complex and not hydrothermal-magmatic.

In his study of the genesis of the ore, Shabynin assigns the determining role to metasomatism, and quite erroneously regards the epigenetic relation of magnetite to many silicate minerals as a sign that it was introduced by the granitic magma. He forgets that magnetite (like many other ore minerals, such as copper, iron, lead and zinc sulfides) is more mobile and susceptible to recrystallization under conditions of repeated metamorphism and migmatization than the silicates and aluminosilicates. It is the mobility of magnetite that was responsible for the formation of transgressive magnetite veinlets, the penetration of magnetite "whiskers" between the grains of the silicates and into their cracks, and for the replacement of diopside, hornblende, scapolite, phlogopite and serpentine by it. Such mobility of magnetite is not peculiar to the Aldan region; it was described by N. A. Eliseev [5] from the ancient metasedimentary iron ores of the Kola Peninsula, in which he distinguished four generations of magnetite. Of considerable interest in this connection is the perfectly correct view of a number of scientists (Schneiderhöhn, Shatskiy and others) that it is necessary to discriminate superimposed (secondary) phenomena of recrystallization and metasomatism from the primary genetic characteristics. In determining the origin of ore deposits, the purely mineralogical and geochemical proofs of eipgenetic origin of ore minerals may be accepted only if the general geological conditions do not contradict them.

Detailed studies and careful examination of the geometric relationship of minerals in thin sections made it possible to establish that in the ore-bearing strata of the Tayezhnoye and Magnetitovoye deposits there is abundant tourmaline of metasedimentary origin syngenetic with the other minerals of the schists, and also tourmaline of later generations, which sometimes resembles the first generation tourmaline but more often is quite different from it in appearance and optical properties. This later tourmaline replaces feldspars, phlogopite, scapolite, pyroxene, hornblende, first generation tourmaline, serendibite and other minerals. In places it occurs in thin transgressive veinlets, or together with quartz forms pods of coarse-grained aggregate (Fig. 9) replacing the material of fine-grained and thinly banded tourmaline paragneisses.

In some cases the superimposed alterations which occurred after the time of the main (regional) metamorphism can be readily traced. This is illustrated by the diopside-andesite-

FIGURE 8. Fine-grained, banded tourmaline paragneiss (with diopside and plagioclase) with thin, locally transgressive veinlets and pods of quartz and feldspar (light).

Sp. G-371/55; Tayezhnoye deposit; actual size.

tourmaline, diopside-tourmaline, hornblende-tourmaline, diopside-phlogopite-tourmaline and epidote-muscovite-tourmaline schists from the iron-bearing beds of the Tayezhnoye and Magnetitovoye deposits [21]. Microscopic examination of these rocks shows definitely that the original metamorphic rock was diopside tourmaline or diopside-plagioclase-tourmaline schist in which diopside was replaced (gradually) by hornblende, phlogopite, epidote and muscovite, and plagioclase by scapolite, phlogopite, epidote and muscovite. However, in all cases the tourmaline (schorl) syngenetic with diopside and plagioclase remained unaltered among the secondary minerals (formed after diopside and plagioclase) or only partially resorbed along the edges.

This account indicates that in separating the superimposed processes we were quite justified by the factual data in not "touching the tourmaline," to use our critic's words, but in considering it as one of the metasedimentary minerals.

The layers and pods of tourmalinized rock subordinate to the near-ore schists and gneisses of the productive iron-bearing beds are traceable with interruptions, like links of a chain connected by thin channels, for hundreds of meters in the similar rock complexes of the Tayeznoye, Magnetitovoye and Tinskoye deposits, while tourmaline-bearing quartzites conformable with the enclosing rocks and ore bodies stretch for tens of kilometers along the Amedichi River. Our ore deposits are comparable, therefore, to the metasedimentary deposits of Malyy Khingan, Krivoy Rog and the Kursk magnetic anomaly, in which the lower, more strongly metamorphosed beds contain magnetite gneisses, pyroxene-hornblende and other silicate-magnetite ores, while the Proterozoic beds near the ore bodies contain chlorite-tourmaline, amphibole-tourmaline and carbonaceous-argillaceous tourmaline paraschists.[3]

In his discussion of the origin of the tourmaline-bearing rocks, Shabynin [30] complains that "D.P. Serdyuchenko enters into a peculiar debate with the authors of the works cited by him. The arguments of the authors (and even factual data) are pronounced unconvincing and exactly the opposite speculative conclusions are substituted for them." Shabynin takes under his "protection" (without presenting any arguments) works whose authors certainly do not need it, as for example, V.A. Sobolev's work on Karsakpay [25] and the papers by G.D. Afanas'yev [1], A.P. Lebedev [9] and others on Malyy Khingan. However, every investigator has the right to criticise published material. Needless to say, it is clearly stated in all of the present writer's works that the idea of the sedimentary-metamorphic origin of tourmaline in paraschists and paragneisses is his own and is not cited from somebody else's work.

This includes the works of foreign scientists on the iron and iron-boron ores of Central Sweden, iron ores of Northern Sweden and the northeastern states of America. All these magnetite ores lie conformably in the enclosing paraschists and paragneisses and exhibit iron

---

[3] Typical paraschists with large prisms of tourmaline containing inclusions of kyanite, garnet, staurolite, acicular sillimanite and flakes of muscovite have been recently described from Northern Scotland [32].

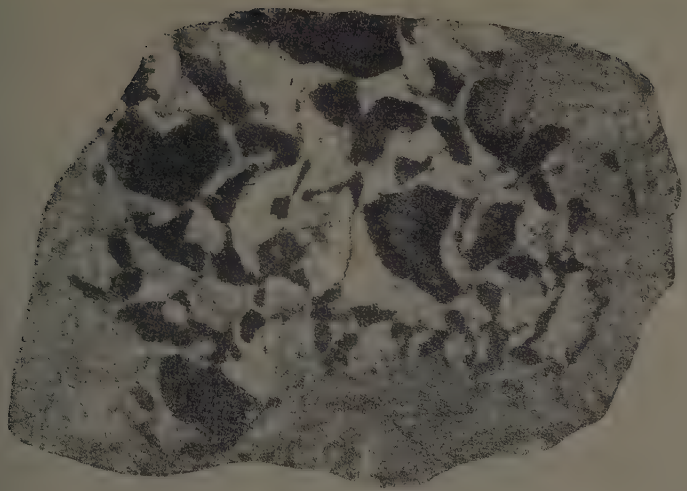

FIGURE 9. Coarse-grained quartz-tourmaline rock formed by recrystallization of foliated fine-grained tourmaline quartzites.

Tayexhnoye deposit, Turmalinovaya Gorka; actual size.

metasomatism (as in the Aldan region) which has no genetic connection with the later granites or characteristic localization in fault or fracture zones.

The same conclusion was drawn by P.N. Chirvinskiy [29] and A.E. Tornebom and, more recently, by the experts on Swedish deposits, Geijer and Magnusson [34], who retained the magmatic hypothesis only for the magnetite-borate areas of Norberg and Långban, although, even there, it cannot withstand the geochemical investigations of Landergren [35, 36]. He showed (partly by the K:Na, RB:K, Fe:Co:Ni, Mg:Fe, V:Ti, Li:Mg, Mg:Ca ratios and other coefficients) that the iron ores bear a clear geochemical relationship to the enclosing metasedimentary rocks and not to the igneous rocks intruded into them. It is known from modern geochemical investigations [2, 26, 33, 35] that boron is concentrated in evaporating sea water by adsorption of suspended clay particles, and for this reason, even in salt deposits, it occurs in clay partings and clayey insoluble residues. But in addition, boron is easily precipitated from sea water with iron, magnesium and manganese compounds.

The desire of some authors to imbue "magnesian skarns" with a special meaning and an intimate genetic relationship with granites is quite arbitrary, because these "skarns" were formed from impure magnesium carbonate sediments (like the metasedimentary magnesites of Bakal-Satka, Angara, Malyy Khingan, Manchuria), especially since the granites, as is well known, do not contain much magnesium. At Norberg, lenses of unaltered or little altered limestones and dolomites and associated iron ores lie conformably with the argillaceous-calcareous (partly volcanic) flysch-like rocks (leptites, hälleflintas) 2.6 km distant from the granite (along a line transverse to the strike). Nearer to the granites the carbonate rocks and ore lenses are changed into skarns. Some of these lenses are "magnesian skarns" (with forsterite, clinohumite, chondrodite) and contain borates (ludwigite, ascharite, fluoborite). Their occurrence and paragenesis are in complete accord with the above mentioned conditions of coprecipitation of magnesite or dolomite (with siliceous and argillaceous admixtures) with iron and boron in sedimentary deposits [31]. The South Yakutian magnetite deposits have the same paragenesis and origin. Here, together with the chemically deposited dolomite (sometimes with admixed fluorite), impure magnesite, magnesium, borates, magnesium-iron borates and iron ores were precipitated in ancient (relict?) basins. In the zone of carbonate and ferruginous sediments, after prolonged and repeated metamorphism and metasomatism the now existing complex

of magnetite- and borate-bearing rocks was formed often spatially related to dolomites. The borates are represented by ascharite, aluminum-iron ascharite, magnesio-ludwigite, ferroludwigite and sometimes kotoite, warwickite, or fluoborite. The mobility of the ludwigites and ascharites and their capacity for recrystallization (as in the case of magnetite) are shown by their occurrence in several generations, and by the fact that during metasomatism they were locally transported and often replace round and irregular patches of carbonate among the silicates and the silicates themselves (phlogopite, chondrodite). During metamorphism the initial concentrations of boron contributed to the formation of tourmaline-bearing rocks in the zone of siliceous clays containing iron and magnesium and to the formation of dumortierite-sillimanite quartzites, in the zone of siliceous clays [23, 24].

Unfortunately, Shabynin barred himself from drawing conclusions so well substantiated by the geochemical data and the actual geological setting by accepting the contact-metasomatic hypothesis in which metasomatism is erroneously taken as an indicator of the magmatic origin of the iron ore and the borates in localized areas of the earth's crust rather than as a mechanism of local transference of these materials and of mineral transformations in the ancient sedimentary cycle.

In the Aldan region the magnetite ores and borates are often, but not always, spatially related to dolomite. But even this relationship does not prove that the carbonate rocks were the precipitants or iron and boron from magmatic (hydrothermal) solutions. The spatial association and the local metasomatic relationship between the calcyphyres and ores could have been inherited from the original sedimentary rocks in which the phenomenon of cold water metasomatism is well known. This phenomenon is illustrated by the basal part of the Jurassic limonites overlying Devonian limestones in the Tula and Lipetsk regions [14] or by the lower beds of the iron-chromium-nickel sedimentary ores of the Malkino deposit of Northern Caucasus lying on weathered serpentinites, etc.

Evidently, the iron ores associated with dolomites and magnesian calc-silicate rocks in Southern Yakutiya, Central Sweden and the northeastern states of the U.S.A. (excluding oolitic hematite-chamosite-siderite ores and ferruginous quartzites) are a distinctive type of ancient metasedimentary deposit. They were formed by chemical deposition of iron on calcareous oozes or on carbonate rocks. In the Archean ores of this type, the iron-bearing rocks are a part of the ancient sedimentary formations, which include beds enriched in silica and alumina, beds containing borates, lenses of impure dolomites, etc. In the course of time, these formations were subjected to repeated metamorphism and igneous intrusions which caused recrystallization, local shifting of the ore material and metasomatism.

Unlike the Archean metasedimentary deposits, the small magnetite ore bodies of the central Aldan region in South Yakutiya (with andradite, pyroxene, phlogopite, clinohumite, hornblende, tremolite) occurring in the contacts of Cambrian dolomites with Upper Jurassic granite porphyry and syenite porphyry laccoliths and dikes are actually contact metasomatics [23]. They are restricted to narrow zones (up to a few meters) along the contact between the igneous rock and the enclosing carbonate beds. Tongues and veinlets of magnetite sometimes penetrate into the joints and between the carbonate beds, but usually for a few meters only, rarely for a few tens of meters [17]. Apart from this magnetite mineralization directly related to igneous bodies, the Cambrian dolomites are not mineralized. Moreover, although there are numerous syenite porphyry dikes, magnetite mineralization is not common and occurs, apparently, only in those cases where the underlying Archean sedimentary beds contain or contained metasedimentary concentrations of iron. Thus the magnetite was partly transported by the syenite-porphyry intrusions cutting through the Archean and Cambrian rocks and, under favorable conditions, redeposited by infiltration metasomatism (in the Cambrian dolomites) in the higher structural level.

REFERENCES

1. Afanas'yev, G.D., PETROGRAFICHESKOYE OPISANIYE PRIAMURSKOY CHASTI MALOGO KHINGANA (PETROGRAPHIC DESCRIPTION OF THE MALLY KHINGAN MOUNTAINS NEAR THE AMUR RIVER]: Tr. Dal'nevost. fil. Akademiya Nauk SSSR, ser. geol., t. 1, 1939.

2. Valyashko, M.G., NEKOTORYYE CHERTY GEOKHIMII BORA. V KN. KHIMIYA BORATOV [SOME FEATURES OF GEOCHEMISTRY OF BORON. IN THE BOOK: CHEMISTRY OF BORATES]: Akademiya Nauk Latv.S.S.R., 1953.

3. Glebov, A.V., TURMALINOVYYE I MAGNETTOVYYE QVARTZITY REKI AMEDICHI V YUZHNOY YAKUTII. SB. OCHERKI OSAD. MESTOROZHD. POLEZN. ISKOPAYEMYKH [TOURMALINE AND MAGNETITE QUARTZITES ON THE AMEDICHI RIVER IN SOUTHERN YAKUTIYA. IN THE BOOK: ESSAYS ON SEDIMENTARY

ECONOMIC DEPOSITS]: Akademiya Nauk SSSR, 1958.

4. Dzevanovskiy, Yu.K. and E.M. Laz'ko, STRATIGRAFIYA ARKHEYA ALDANSKOGO SHCHITA [ARCHEAN STRATIGRAPHY OF THE ALDAN SHIELD]: Geol. sb. L'vovsk. geol. o-va, no. 2-3. Izd. L'vovsk. in-ta, 1956.

5. Eliseyev, N.A., STRUKTURNAYA PETROLOGIYA [STRUCTURAL PETROLOGY]: Izd. LGU, 1953.

6. Korzhinskiy, D.S., ARKHEYSKIYE MRAMORY ALDANSKOY PLITY I PROBLEMA FATSIY GLUBINNOSTI [ARCHEAN MARBLES OF THE ALDAN PLATE AND THE PROBLEM OF DEPTH FACIES]: L.-M., ONTI, 1936.

7. __________, PETROLOGIYA ARKHEYSKOGO KOMPLEKSA ALDANSKOY PLITY (PERESECHEN'YE PO REKE TIMPTON) [PETROLOGY OF THE ALDAN PLATE (SECTION ALONG THE TIMPTON RIVER)]: L.-M., ONTI, 1936.

8. Kotul'skiy, V.K., GEOLOGICHESKIYE ISSLEDOVANIYA V VITIM-KANSKOM ZOLOTONOSNOM RAYONE V 1909 GODU [GEOLOGICAL INVESTIGATIONS IN THE VITIM-KANA GOLD-BEARING REGION IN 1909]: Tr. Vses. Geol.-razved. ob"edin., vyp. 197, 1932.

9. Lebedev, A.P., PETROGRAFICHESKIYE ISSLEDOVANIYA NA MALOM KHINGANE V 1935 GODU [PETROGRAPHIC INVESTIGATIONS IN THE MALYYI KHINGAN RANGE IN 1935]: Tr. Dal'nevost. fil. Akademiya Nauk SSSR, ser. geol., t. 1, 1939.

10. Litsarev, M.A., GROSSYULARO-VOLLASTONITOVYYE SKARNY EMEL'DZHAKSKOGO FLOGOPITOVOGO MESTOROZHDENIYA (YUZHNAYA YAKUTIYA) [GROSSULARITE-WOLLASTONITE SKARNS OF THE EMEL'DZHAK PHLOGOPITE DEPOSIT (SOUTHERN YAKUTIYA)]: Izvdstiya, Akademiya Nauk SSSR, ser. geol., no. 3, 1958.

11. Marakushev, A.A., PETROLOGIYA TAYEZHNOGO ZHELEZORUDNOGO MESTOROZHDENIYA V ARKHEE ALDANSKOY PLITY [PETROLOGY OF THE TAYEZHNYYI IRON DEPOSIT IN THE ARCHEAN OF THE ALDAN PLATE]: Avtoref. dis. kand. g.-m. nauk, 1956.

12. Oaerov, K.N. and N.A. Bykhover, MESTOROZHDENIYA KORUNDA I KIANITA VERKHNE TIMPTONSKOGO RAYONA YAKUTSKOY ASSR [CORUNDUM AND KYANITE DEPOSITS OF THE UPPER TIMPTON REGION OF THE YAKUT ASSR]: Tr. Tsentr. n.-i. geol.-razved. in-ta, vyp. 82, 1936.

13. Pervago, V.A., ALDANSKAYA ZHELEZORUDNAYA PROVINTSIYA (RAYONIROVANIYE I PERSPEKTIVY) [THE ALDAN IRON PROVINCE (SUBDIVISION AND PROSPECTS)]: Sov. geologiya, no. 8, 1958.

14. Pustovalov, L.V., GENEZIS LIPETSKIKH I TUL'SKIKH ZHELEZNYKH RUD V SVETE GEOKHIMICHESKOY ISTORII YUZHNOGO KRYLA PODMOSKOVNOGO BASSEYNA [THE ORIGIN OF LIPETSK AND TULA IRON ORES IN THE LIGHT OF GEOCHEMICAL HISTORY OF THE SOUTHERN LIMB OF THE MOSCOW BASIN]: Tr. Geol.-razved. ob"edin. NKTP SSSR, vyp. 285, 1933.

15. __________, KRATKAYA KHARAKTERISTIKA GLAVNEYSKIKH TIPOV OSADOCHNYKH ZHELEZNYKH RUD. V KN. ZHELEZORUD. BASA CHERN. METALLURGII SSSR [A BRIEF CHARACTERISTIC OF THE TYPES OF SEDIMENTARY IRON DEPOSITS. IN THE BOOK: IRON ORE RESERVES FOR SOVIET METALLURGY]: Tr. Mezhduved. Postoyan. komis. po zhelezu. M. 1957.

16. Semenenko, N.P., GEOLOGIYA I PETROGRAFIYA MAMSKOY KRISTALLICHESKOY POLOSY [GEOLOGY AND PETROGRAPHY OF THE MAMA CRYSTALLINE BELT]: Akademiya Nauk Ukr.S.S.R., 1948.

17. Serdyuchenko, D.P., ZHELEZNYYE RUDY ALDANSKOGO GORNOPROMYSHLENNOGO RAYONA. V KN. KOKSUYUSHCHIYESYA KAMEN. UGLI I ZHELEZN. RUDY ALDANSKOGO GORNOPROMYSHLENNOGO RAYONA YAKUTSKOY ASSR [IRON ORES OF THE ALDAN MINING REGION: IN THE BOOK: COKING COALS AND IRON ORES OF THE ALDAN MINING REGION OF YAKUT ASSR]: Akademiya Nauk SSSR, 1952.

18. __________, ZHELEZNYYE RUDY ALDANA, IKH MINERALOGOPETROGRAFICHESIYE OSOBENNOSTI I GENEZIS. V KN. PROBL. CHERN. METALLURGII NA BAZE RUD I KAMEN. UGLEY YUZHNOY YAKUTII [IRON ORES OF THE ALDAN REGION, THEIR MINERALOGICAL-PETROGRAPHICAL CHARACTERISTICS AND ORIGIN. IN THE BOOK: PROBLEMS OF FERROUS METALLURGY IN CONNECTION WITH THE ORES AND COALS OF SOUTHERN

YAKUTIYA]: Tr. Yakutskoy kompleksnoy ekspeditsii, 1955.

19. __________, KALIYEBYYE SKAPOLITY IZ YUZHNOY YAKUTII. VOPR. GEOLOGII AZII, t. 2 [POTASH SCAPOLITES FROM SOUTHERN YAKUTIYA. PROBLEMS OF GEOLOGY OF ASIA, v, 2]: AKADEMIYA NAUK SSSR, 1955.

20. __________, O NEKOTORYKH BOTATYKH BOROM OSADOCHNOMETAMORFICHESKIKH FATSIYAKH [ON CERTAIN BORON-RICH METASEDIMENTARY FACIES]: Doklady, Akademiya Nauk SSSR, t. 102, no. 4, 1955.

21. __________, O NEKOTORYKH TIPAKH OSADOCHNO-METAMORFICHESKOGO MINERALOOBRAZOVANIYA. V KN. VOPR. MINERALOGII OSADOCHN. OBRAZOVANIY, KN. 3-4 [ON CERTAIN TYPES OF METASEDIMENTARY MINERAL FORMATION. IN THE BOOK: PROBLEMS OF MINERALOGY OF SEDIMENTARY ROCKS, VOLS. 3-4]: Izd. L'vovsk. Un-ta, 1956.

22. __________, MINERALY BORA I TITANA V NEKOTORYKH OSADOCHNO-METAMORFICHESKIKH PORODAKH [BORON AND TITANIUM MINERALS IN SEDIMENTARY ROCKS]: Tr. Geol. in-ta, vyp. 5, 1956.

23. __________, MAGNESIOFERRITY I TITAN-SHPINELI IZ ARKHEYSKOGO KOMPLEKSA YUZHNOY YAKUTII [MAGNESIOFERRITES AND TITAN-SPINELS FROM THE ARCHEAN COMPLEX OF SOUTHERN YAKUTIYA]: Mineralog. sb., no. 12. Izd. L'vovsk. un-ta, 1958.

24. __________, O SOSTAVE I GENEZISE DYUMORT'YERITOV [COMPOSITION AND GENESIS OF DUMORTIERITES]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 2, 1958.

25. Sobolev, V.S., MATERIALY PO PETROGRAFII METAMORFICHESKIKH I IZVERZHENNYKH POROD KARSAKPAYSKOGO RAYONA TSENTRAL'NOGO KAZAKHSTANA [PETROGRAPHY OF METAMORPHIC AND IGNEOUS ROCKS OF THE KARSAKPAY REGION OF CENTRAL KAZAKHSTAN]: Zap. Vses. mineralog. o-va, ch. 67, vyp. 1, 1938.

26. Strakhov, N.M. and I.D. Borneman-Starnykevich, O STRONTSII, BORE I BROME V PORODAKH NIZHNEPERMSKOY GALOGENNOY TOLSHCHI BASHKIRSKOGO PRIURAL'YA. V KN. VOPR. MINERALOGII, GEOKHIMII I PETROGRAFII [STRONTIUM, BORON AND BROMINE IN THE LOWER PERMIAN SALT BEDS OF BASHKIRIYA]: Akademiya Nauk SSSR, 1956.

27. Sudovikov, N.G., ZHELEZO-MAGNEZIAL'NO-KAL'TSIEVYYI METASOMATISM V ARKHEE ALDANSKOGO SHCHITA I NEKOTORYYE VOPROSY "OSNOVNOGO FRONTS" [IRON-MAGNESIUM-CALCIUM METASOMATISM IN THE ARCHEAN OF THE ALDAN SHIELD AND CERTAIN PROBLEMS OF THE "BASIC FRONT"]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 1, 1956.

28. Fersman, A.E., PEGMATITY [PEGMATITES]: t. 1, Akademiya Nauk SSSR, 1940.

29. Chirvinskiy, P.N., OTCHET O KOMANDIROVKE NA MEZHDUNARODNUYU XI GEOLOGICHESKIY KONGRESS V STOKGOL'ME V AVGUSTE 1910 GODA S KRATKIM OPISANIYEM GEOLOGICHESKOGO STROYENIYA POSESHCHENNYKH MESTOROZHDENIY POLEZNYKH ISKOPAYEMYKH I SOBRANNYKH KOLLEKTSIY [REPORT OF ATTENDANCE AT THE XI INTERNATIONAL GEOLOGICAL CONGRESS IN STOCKHOLM IN AUGUST 1910 WITH A BRIEF DESCRIPTION OF THE GEOLOGICAL STRUCTURE OF THE VISITED ORE DEPOSITS AND OF THE COLLECTIONS MADE BY THE AUTHOR]: Izv. Donsk. politekhn. in-ta, t. 1, otd. 2, 1912.

30. Shabynin, L.I., O GENEZISE YUZHNO-YAKUTSKIKH ZHELEZORUDNYKH MESTORPZHDENIY [ON THE GENESIS OF THE SOUTH YAKUTIAN IRON DEPOSITS]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 1, 1958.

31. Fersman, A.E., GEOKHIMIYA [GEOCHEMISTRY]: v. 4, Goskhimizdat, 1939.

32. Clifford, T.N., A NOTE ON KYANITE IN THE MOINE SERIES OF SOUTHERN ROSS-SHIRE AND A REVIEW OF RELATED ROCKS IN THE NORTHERN HIGHLANDS OF SCOTLAND: Geol. Mag., no. 4, 1958.

33. Heide, F. and A. Thiele, DER BORGEHALT DES SAALWASSERS: Naturwissenschaften, H. 15, 1958.

34. Geijer, P. and N. Magnusson, GEOLOGICAL HISTORY OF THE IRON ORES OF CENTRAL SWEDEN: Rep. XVIII Intern. Geol. Congr., 1948, p. 13, London, 1952.

35. Landergren, S., THE DISTRIBUTION OF

BORON IN SOME SWEDISH SEDIMENTS, ROCKS AND IRON ORES. THE BORON CYCLE IN THE UPPER LITHOSPHERE: Arkiv. kemi, mineral. geol., Bd. 19A, Hf. 5, no. 26, 1945.

36. ___________, ON THE GEOCHEMISTRY OF SWEDISH IRON ORES AND ASSOCIATED ROCKS: Sverig. geol. Undersökn., ser. C., no. 496, Stockholm, 1948.

Soviet for the Study of Economic Reserves,
Academy of Sciences, U.S.S.R.
Moscow

Received June 9, 1958

NEW DATA ON THE GRANITOIDS OF THE MAIN RANGE IN THE NORTHWESTERN CAUCASUS[1]

by

— V. V. Sviridov —

From 1955 to 1958 the author studied granitoid massifs of the Main Range in the basin of the upper tributaries of the Urushten, Sinyaya and Imeretenka rivers (village of Chelepsoy) and in the upper reaches of the Kisha River (Fig. 1). Outcrops of granitoids were discovered on the Dzitaku, Pereval'naya and Pseashkha mountains, and large massifs of diorite and gabbro gneiss in the upper waters of the Kisha and Laura rivers.

Brief accounts of the petrography of these areas may be found in the published papers by I. Ya. Baranov [2, 3], L. A. Vardanyants [5] and A. G. Kobilev [7]. It was pointed out in a monograph on the granitoids of the northwestern Caucasus by G. D. Afanas'yev [1] that the region to the west of the upper waters of the Malaya Laba River has been little studied and that the information about it is fragmentary.

The results of investigations reported in the present paper fill the gap in our knowledge of granitoids from one of the interesting regions of Northern Caucasus.

MAIN FEATURES OF THE GEOLOGICAL SETTING OF THE GRANITOIDS

The Main Range has anticlinal structure. In the investigated region the axis of the anticline plunges to the northeast, and as a result, in the basin of the Sinyaya River, the granitoids of the core of the anticline are unconformably overlain by Liassic arenaceous-argillaceous beds containing from eight to ten meters of basal conglomerate.

We shall describe a granitoid body which will be called the Verkhne-Urushtenskiy massif. In the northwest and south it has a normal stratigraphic contact with the Lias; in the north, an intrusive contact with schists; and in the east it passes into the Hercynian Malaya Laba granitic massif studied by Afanas'yev.

To the south of the Verkhne-Urushtenskiy massif in the watershed zone of the Main Range (Pereval'naya subzone), among Jurassic rocks, there is a belt of metamorphosed Lower Carboniferous sedimentary beds from five to seven kilometers wide and trending in the general direction of the Caucasus from northwest to southeast.

The Lower Carboniferous rock complex is represented by phyllites, subordinate quartzites, conglomerates, metamorphosed limestones and cherts.

The contacts between the Liassic shales and the Lower Carboniferous phyllites are mainly tectonic and are difficult to trace in the field because the argillaceous rocks of both systems are very similar in appearance and have the same attitude with the dips to the northeast ranging from 15° to 40°, 35° to 40° and 70° to 80°. In this subzone, ancient granitoid gneisses and quartz-amphibole gneisses containing gabbro-diorite relicts have been brought up by faults to the level of the Lower Carboniferous strata. The metamorphosed igneous rocks, especially the Lower Carboniferous strata, often contain sills and thin dikes of andesine- or labradorite-hornblende spessartite.

Occasionally dikes of hornblendite and albitophyre almost indistinguishable from the spessartites are found. In the Liassic zone of the Main Range to the north of the Verkhne-Urushtenskiy massif, diabase dikes similar in composition to the spessartite dikes are occasionally encountered. To the south of the Pereval'naya subzone (on the southern slope of the Main Range) the Lower Jurassic rocks are frequently intruded by steeply dipping diabase sills, but of an entirely different composition. None of these hypabyssal rocks is found in the Verkhne-Urushtinskiy massif or in the microcline granite of the Pereval'naya subzone.

[1] Novyye dannyye o granitoidakh glavnogo khrebta na severo-zapadnom kavkaze.

In the uppermost reaches of the Kisha River a tectonic granite block was noted long ago by V. N. Robinson and V. A. Mel'nikov and referred by them to the granites of the Main Range. The writer also found a rather large block of gneiss in this region containing apparently two or three granite dikes with an area of 0.2 to 0.3 square kilometers each. The foliation in the contact gneissoid granites and the enclosing gneisses coincide in a general way with the attitude of the Lower Carboniferous phyllites. The same is true of the gneissoid granitoids outcropping on the Pereval'naya, Dzitaku and Pseashkha mountains.

PETROGRAPHIC DESCRIPTION OF THE PEREVAL'NAYA SUBZONE GRANITES

1. Granitoids of the Kisha River

The granitoids include leucocratic and two-mica plagiogranites and pegmatoidal granites. The latter occur as small veins in the former.

The leucocratic and two-mica plagiogranites are gray, noticeably crushed medium-grained rocks very similar to each other in composition and texture. The microscope shows a cataclastic texture with areas of intensive

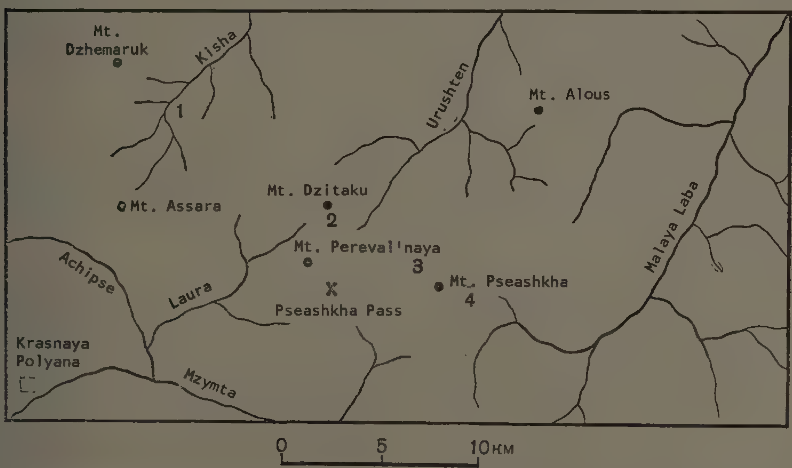

FIGURE 1. Index map of the western part of the Main Range of the Caucasus. Numbers on the map indicate newly found granitoid outcrops.

Most of the outcropping granitoids are lens-like tectonic blocks, probably conformable with the enclosing Lower Carboniferous rocks. Immediate contacts of the granitoids with the Lower Carboniferous rocks were found only on the Pereval'naya, Dzitaku and Pseashkha mountains (under Kholodnyy glacier). Inasmuch as these contacts have characteristic features, a description of the Lower Carboniferous contact rocks is given below. On Mt. Dzitaku, microcline granite is in intrusive contact with small-pebble conglomerate; on Mt. Pereval'naya, the contact between the granitoids and the phyllites is tectonic; and on Mt. Pseashkha, the conglomerates lie unconformably on the leucocratic granites.

fragmentation and recrystallization of the component minerals. The granites are massive and gneissoid. The essential minerals are plagioclase (albite-oligoclase), quartz, and biotite, and in the two-mica granites, muscovite. The secondary minerals are sericite, calcite, light-green chlorite (Oennine), epidote and vein quartz. The accessory minerals are prismatic apatite, brownish sphene, idiomorphic crystals of zircon and grains of magnetite.

The pegmatoidal granites contain muscovite crystals three to five centimeters in diameter in a medium-grained groundmass.

The modes of the Kisha River granitoids

Table 1

Mineralogical Composition of Granitoids and Gneisses

Minerals	Kisha River				Mt. Pereval'naya			
	plagiogranites			pegmatoidal granites	plagiogranites		granodiorite	tonalite
	leucocratic		two-mica		melanocr. biotite	two-mica		
	sp. 2020	sp. 2022	sp. 185	sp. 948	sp. 1603-a	sp. 1608-a	sp. 1605-g	sp. 1654-v
Plagioclase	64,9	55,2	59,8	29,6	41,0	53,0	62,0	73,2
Potash-soda feldspar	4,3	—	—	—	—	rare	—	1,9
Quartz	25,4	40,3	29,9	45,3	37,3	34,6	25,0	15,4
Biotite	2,7	1,9	10,3	—	21,4	7,0	12,0	9,5 (chloritized)
Muscovite	—	—		25,1	—	4,5		—
Amphibole	—	—	—	—	—	—	—	—
Secondary Minerals	2,7	2,6	—	—	—	—	—	—
Accessory and ore minerals			—	—	0,3	0,9	1,0	—
Total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Note: Comma represents decimal point.

as well as of the rocks from the newly discovered outcrops are presented in Table 1.

2. The Granitoids of the Northern Slope of Mt. Pereval'naya and the Southern Slope of Mt. Dzitaku

On Mt. Pereval'naya there are outcrops of melanocratic biotite granites, two-mica granites, metamorphosed plagiogranites and granodiorites and tonalites. The plagiogranites occur in the eastern part of the massif, while their metamorphosed equivalents and granodiorites and tonalites occur in the western part.

The melanocratic biotite plagiogranites are dark-gray medium-grained strongly gneissoid rocks. The microscope reveals hypidiomorphic cataclastic texture. The essential minerals are plagioclase (albite-oligoclase), quartz and biotite, the accessories are zircon, rutile and rounded grains of apatite and magnetite.

The two-mica plagiogranites and conspicuous among other rocks by their freshness, light-gray color and weak foliation. The microscope shows the same textural relations as in the rocks described above but with less cataclasis. The essential minerals are plagioclase (albite), quartz, biotite, muscovite, and occasional grains of microcline. The accessories include zircon and numerous magnetite grains.

Crushed crystals of microcline microperthite with poorly developed grid structure are occasionally seen. The microcline contains relict grains of plagioclase-quartz myrmekite.

The metamorphosed plagiogranites are gray massive or foliated rocks. The microscope shows strongly cataclastic, gneissoid, almost schistose structure. The deformed plagioclase tablets are slightly sericitized albite containing calcite in the fractures. Biotite is completely altered into a fine scaly aggregate, and together with fine-grained quartz resorbs the plagioclase. Hornblende occurs occasionally in clusters of small (about 0.1 mm) acicular or rod-like crystals; it is pleochroic, with γ = light-green and α = pale green; $c{:}\gamma$ = 13-15°. The accessory minerals are zircon and magnetite as in the plagiogranites.

The texture of the banded foliated plagiogranites (metagneisses) is heterogranoblastic.

Among the melanocratic biotite plagiogranites there are outcrops of dark-green amphibolites which represent relicts of diorite or gabbro gneisses. Under the microscope the amphibolites show blastomylonitic texture.

Table 1, continued

Mt. Dzitaku			Kholodnyi glacier			Malaya Laba River	Quartz-amphibole		
biotite plagio-granite	microcline granite		biotite plagiogranite		microcline granite	grano-diorite	gabbro-gneiss	diorite-gneiss	
							Kisha River	Laura River	
sp. 1609-a	sp. 7-oz	sp. 17-oz	sp. 1-kh	sp. 8-khol	sp. Gr-Sr (average of 4)	sp. 2808	sp. 954	sp. 2085	sp. 287
60,1	13,3	4,1	55,3	58,8	26,8	61,7	42,2	54	46,5
—	35,9	31,8	—	—	44,7	6,2	—	—	—
28,8	37,0	40,2	39,0	31,3	21,2	19,0	17,7	19	25,7
10,3	7,4	16,5	4,7	8,8	4,3	12,8	2,0	11	—
—	5,4	5,4	—	—	—	—	—	—	—
—	—	—	—	—	—	0,7	37,0	12	25,5
—	—	—	—	—	—	—	—	4	2,3
1,5	1,0	2,0	1,0	1,1	1,2	—	1,1		
100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

They are composed of grains of light-green hornblende with a bluish tinge ($c{:}\gamma = 17°$, $-2V = 80°$, $\gamma\text{-}\alpha = 0.018$) and sericitized comminuted feldspathic mass.

The granodiorites are similar in outward appearance to the melanocratic biotite plagiogranites, but are somewhat more massive and contain fewer femic minerals.

The microscope reveals their cataclastic texture and the essential minerals, plagioclase (oligoclase-andesite), quartz, biotite and muscovite. The secondary minerals are sericite and chlorite, and the accessory, zircon and magnetite.

On Mt. Dzitaku there are two varieties of granitoids: a) the biotite plagiogranites with albitite veins, forming the main part of the outcrop, and b) the microcline granites at the contact between the granitoids and the Lower Carboniferous metasedimentary rocks.

In the transitional microcline granite — plagiogranite zone (0.5 to 0.7 m wide) there is a crushed dark-gray medium-grained rock composed of black graphite scales, and quartz in an aphanitic quartz-sericite groundmass containing albite-oligoclase grains.

Both varieties are gray, medium-grained, gneissoid rocks with cataclastic texture.

The biotite plagiogranites are composed of albite, quartz and biotite, the secondary minerals being chlorite, muscovite and veinlets of calcite with pyrite and the accessories, apatite, sphene, magnetite and zircon. Chlorite replaces biotite, and hematite replaces ore minerals.

In the plagiogranites, conformably with their foliation, lies a vein of albitite 30 to 35 cm in thickness. The albite is a white coarse-grained rock showing the effects of dynamic metamorphism. The microscope shows that it contains crushed, originally idiomorphic albite crystals (An_5) and no more than 2 to 5 percent of small quartz grains.

The microcline granites are characterized by sharp predominance of quartz and microcline over plagioclase and a considerable content of biotite and muscovite. The secondary minerals are chlorite and sericite; the accessory, zircon and pyrite.

The granitoids beneath the Kholodnyy glacier. On the left tributary of the Kholodnaya River, near its source, beneath the Kholodnyy glacier (Mt. Pseashkha), a granitoid massif is exposed composed of biotite plagiogranite with quartz-plagioclase veins in the northeast and microcline granite in the southwest. The transitional zone between the two varieties of granite is concealed under a

cover of deluvium or lies in inaccessible cliffs.

The biotite plagiogranite is dark-gray and gray medium-grained rock. Porcelain-like gray, almost white, tabular feldspar crystals 0.5 to 0.15 mm, but more frequently 1 to 3 mm in size, are weathered in relief on the exposed surfaces. The plagiogranite is faintly porphyritic.

The microscope reveals monzonitic cataclastic texture. The essential minerals are plagioclase (albite-oligoclase), quartz and biotite, and the accessory minerals are represented by numerous dotlike magnetite grains, occasional sagenite in biotite, and infrequent grains of zircon, epidote, apatite and sphene.

The mylonitized biotite plagiogranite is foliated brown-gray fine-grained rock resembling quartzose sandstone. The microscope reveals mylonitic and locally cataclastic texture. The rock is composed of finely ground and recrystallized quartz-biotite-feldspar material. Occasionally, deformed plagioclase crystals (An_{10}) are seen and, less frequently, grains of quartz sphene and epidote.

The quartz-plagioclase veins in the biotite plagiogranites are white and coarse-grained and up to 15 to 20 centimeters in width. The predominant mineral in these veins is kaolinized plagioclase, oligoclase (An_{13} - An_{15}) with fine albite twinning. The secondary minerals are quartz, occurring in thin veinlets, and chloritized biotite, developed along the cleavage cracks in the plagioclase.

The microcline granite is gray porphyritic crushed rock. Its fractured light-gray and pinkish feldspar phenocrysts are up to 10 to 15 millimeters length. The groundmass consists of feldspar and quartz fragments (1 to 3 mm) and a small amount of an aggregate composed to minute biotite flakes and quartz and feldspar grains.

The microscope shows that the feldspar phenocrysts are microcline microperthite ($-2V$ = 82 to 84°) and the groundmass is fine-grained biotite-quartz-feldspar material. The secondary minerals include light-green chlorite (pennine) developed after biotite, and sericite and epidote developed after plagioclase. The accessory minerals are magnetite, zircon and apatite. Crystals of colorless idiomorphic epidote and broken grains of colorless garnet are occasionally seen.

The leucocratic granite is light-gray, almost white, medium-grained and rather strongly foliated rock. The microscope shows that it has cataclastic texture and is composed of plagioclase, quartz and a small amount of untwinned brown microcline. The accessory minerals include brownish ores and small colorless prisms of apatite and zircon.

The torn and deformed crystals of plagioclase (An_{10}, seldon An_2) are partially replaced by microcline. Some plagioclase crystals contain quartz in myrmekitic intergrowth.

The primary quartz, which is sometimes preserved as fractured grains up to two millimeters in diameter, show strong effects of cataclasis. It is usually fragmented and recrystallized into a mosaic of small grains. In the fine-grained, essentially quartzose groundmass, there are minute lenses and veinlets of idiomorphic quartz (0.03 to 0.09 mm in diameter). The aphanitic, essentially quartzose groundmass passes into an almost amorphous matrix with scales of muscovite and light-green chlorite.

3. The Granitoids of the Malaya Laba River

In the uppermost reaches of the Malaya Laba River, on the eastern slope of Mt. Pseashkha, there are outcrops of plagiogranite similar to those beneath the Kholodnyy glacier and of cliff-forming unaltered massive granodiorite which is probably younger than the plagiogranite.

The microscope shows that the granodiorite has hypidiomorphic texture and is composed of plagioclase (An_{35}), quartz, microcline, biotite and hornblende. Prismatic apatite, rounded yellowish zircon crystals and occasional colorless slightly fractured grains of garnet are the accessory minerals. The first generation biotite contains pleochroic halos with a radius of 0.015 millimeters formed around grains of zircon.

The plagioclase is resorbed by quartz and replaced by microcline.

The rock contains small scales of pale-brown second generation biotite. The biotite occurs in clusters and penetrates into the cleavage cracks in plagioclase.

The hornblende is found infrequently in xenomorphic or prismatic grains. It is pleochroic from light-green (γ) to dirty green (β) and pale-green (α). The extinction angle $c{:}\gamma$ = 17°. Sometimes it is replaced by biotite and chlorite.

4. Quartz-Amphibole Diorite and Gabbro Gneisses

Since these rocks have not been studied before, a brief description of them is necessary.

The amphibole gneisses formed at the expense of quartz diorite and gabbro occur mainly in the upper reaches of the Laura and Kisha rivers. They are dark-green and grayish-green, often banded, foliated coarse-grained, medium-grained and, less frequently, fine-grained rocks. The Kisha River gneisses are the most intensively metamorphosed. They contain almost no relicts of igneous rocks and have the appearance of normal amphibole gneisses and amphibolites.

The texture of the gneisses is blastocataclastic. In the strongly metamorphosed Kisha gneisses it approaches fibro-lepidogranoblastic texture, for here quartz grains have serrated contacts and form a mosaic and the hornblende in the dark bands is recrystallized into fibrous-acicular actinolite or altered to scaly chlorite. Sometimes it is altered to muscovite, light-brown biotite or epidote.

Sometimes the amphibole gneisses contain layers of light-gray almost white fine-grained gneissoid rock 3 to 6 mm thick which merge gradually into the enclosing gneiss. These rocks are composed of mosaic or granoblastic quartz and extremely fine mylonitized material, evidently quartz-feldspar, containing occasional deformed plagioclase crystals. The plagioclase (An_{30}) is kaolinized, sericitized and sometimes saussuritized. The quartz bands contain scales of green chlorite, biotite and muscovite. The accessory minerals are apatite and zircon. These leucocratic gneissoid rocks were evidently formed from aplites.

In the gneiss massif of the Laura River, gneisses of high metamorphic rank are found only in the deeper parts of the section, while its central parts consist of massive, only slightly gneissoid rocks. In them, in spite of the development of porphyroblasts and cataclasis, the plagioclase and hornblende crystals retain the original tabular and prismatic habit. The material of the salic components or recrystallized quartz penetrates into the cracks in these crystals.

The essential minerals in the gneisses are plagioclase, hornblende and quartz; the accessory minerals are ilmenite with sphene, zircon, apatite and, infrequently, magnetite and pyrite. The modes of these rocks are presented in Table 1.

The plagioclase and the hornblende crystals show alignment induced by intensive dynamic metamorphism.

The hornblende is green, in some cases spotted, because of the irregular distribution of color. The prismatic hornblende crystals average 1 to 2 mm in length. They are pleochroic, with γ = green, β = dark yellowish-green and α = yellowish-green. The optical constants of the hornblende obtained on the universal stage are as follows:

Specimen No.	$c{:}\gamma$	2V	$\gamma-\alpha$
1754-a	14°	-78°	0.022
287	16°	-70°	0.022
2072	16°	-80°	0.019
182	14°	-86°	–
1750	19°	-78°	–

The characteristic alteration of the hornblende is the replacement by pale-brown biotite (2V about -10°), chlorite and epidote (2V = -76°, -84°). Sometimes a large hornblende crystal is changed into an aggregate of small blue-green hornblende ($c{:}\gamma$ = 17°).

Quartz, being a brittle mineral, is usually crushed and recrystallized into small grains.

The contacts between the granitoids and the Lower Carboniferous rocks were found on the slopes of the Pereval'naya, Dzitaku, and Pseashkha mountains. On Mt. Pereval'naya the contact is tectonic. Near it are light-gray, fine-grained crystalline limestones. Lenses of granitoids were found in the sericitized shales.

The thickness of the granitic lenses and augen in the shales ranges from fractions of a centimeter to 1.5 to 2 cm. They are composed of rolled and stretched albite-oligoclase grains with micropegmatitic intergrowths of quartz and fine-grained ground up quartzo-feldspathic mass containing scales of light-brown biotite and of muscovite. The accessory minerals are zircon, magnetite, apatite and sometimes tourmaline with $\gamma - \alpha$ = 0.018 to 0.020.

On Mt. Dzitaku the microcline granites are in contact with the Lower Carboniferous metamorphosed sedimentary rocks, small-pebble conglomerates, sandstones, cherts enclosing beds of black limestone and phyllitized shales.

The small-pebble conglomerates and sandstones are composed of rounded crushed and recrystallized quartz grains and subordinate saussuritized plagioclase. The cementing material is quartz-sericite. The rocks contain small muscovite flakes occurring in microaggregates and separately and prismatic and anhedral crystals of tourmaline resembling in its optical properties the tourmaline of the near-contact granites of Mt. Pereval'naya. The cement of the sandstones contains biotite.

The chert-like shales are dense banded rocks (with alternating gray and dark-green bands). The light bands are composed essentially of minute quartz grains and somewhat

altered albite-oligoclase. In the dark-green bands the predominant mineral is bluish light-green hornblende in slender prismatic crystals; it is sometimes replaced by biotite. Sericite, sphene, leucoxene, epidote and apatite occur in the dark bands.

The black metamorphosed limestone is dense, fine-grained and contains admixed carbonaceous-argillaceous material with numerous grains of a metallic mineral.

The phyllitized shales are dark-gray, almost black. Their banded structure is due to the presence of layers of carbonaceous-argillaceous material in a fine-grained quartz-sericite groundmass.

On Mt. Pseashkha the granitoid, leucocratic granite in this case, is in contact with the Lower Carboniferous rocks, conglomerate (0.5 to 1 m thick), overlain by quartzose sandstones (2 to 3 m thick) and marbles (up to 30 meters in thickness).

Granite pebbles 3 to 12 centimeters in diameter and smaller predominate in the conglomerate. The granite of the pebbles is composed of quartz (up to 50-60%), muscovite and chlorite (together amounting to 8%) and plagioclase (An_{12}). The granite is intensively crushed and contains quartz muscovite symplectic intergrowths. In the fine-grained mylonitized groundmass of the granite, there are crushed grains of sphene leucoxene, zircon, apatite and carbonate. Zircon inclusions in chlorite are surrounded by pleochroic halos up to 0.036 millimeters in radius.

The quartzose sandstones are fine-grained, and macroscopically resemble the sandstones of Mt. Dzitaku but are less metamorphosed and have no biotite in the cement.

The marbles are similar to the metamorphosed limestones of Mt. Pereval'naya.

SUMMARY OF THE GRANITOIDS AND GNEISSES OF THE PEREVAL'NAYA SUBZONE

The newly discovered granitoid outcrops described here for the first time can be divided into two large groups.

The first group includes various plagioclase granites (plagiogranites) with albitite and quartz-plagioclase veins, granodiorites and tonalites of Mt. Pereval'naya and the leucocratic granites from beneath the Kholodnyy glacier. The predominant minerals in these rocks are plagioclase, often albitized, and among the femic minerals, biotite. The potash feldspar, brown due to kaolinization, is near to orthoclase in its properties but not always so.

The chemical analyses show that the leucocratic granites and the biotite plagiogranites (Tables 2 and 3) are oversaturated with alumina. The values of their n characteristic indicate strong excess of sodium over potassium.

These characteristics prove that the rocks of the first group are identical with the granitoids of the Urushtenskiy complex (Afanas'yev's data). The investigated amphibole gneisses are also similar to the rocks of this complex and, as shown by geological and petrographic studies, they form a substratum for the plagiogranite intrusions. Mineralogically and chemically the gabbro and diorite gneisses of the region are similar to the amphibole gabbros investigated by Afanas'yev in the more easterly regions of the Pereval'naya subzone (upper waters of the Mark and Aksaut rivers).

The second group includes microcline granite and the fresh massive granodiorite from near the source of the Malaya Laba River. The age of these rocks is probably Variscan, for they metamorphosed the enclosing Lower Carboniferous strata. Their characteristic feature is the presence of over 5% of fresh microcline with more or less developed grid structure.

Thus, the first group of the granitoids (including gneisses) matches the Urushtenskiy complex (Lower Paleozoic) and the second group matches the granitoid complex of the Main Range (Middle Paleozoic).

THE VERKHNE-URUSHTENSKIY GRANITOID MASSIF

During the geologic mapping of this area a large collection of rocks was made and a petrographic study of these specimens revealed the complex structure of the massif (Fig. 2). The larger part of it is composed of microcline granite with areas of quartz diorite, biotite, granodiorite and orthoclase granite.

Contact relations were observed between some of the granitoids. For example, in the contact zone between quartz diorite and microcline granite there occurs coarse-grained quartz diorite, or sometimes foliated fine-grained quartz diorite containing carbonate veinlets two to five centimeters in thickness.

In the northern region, porphyritic granites are foliated at the contact with leucocratic microcline granites and have granodioritic composition.

Table 2

Chemical Composition of Granitoids and Gneisses of the Main Range[a]

Components	Leucocratic plagiogranite, sp. 2022		Biotite plagiogranite, sp. 1-kh.		Microcline granite (Verkhne-Urushtenskiy massif), sp. 28		Microcline granite (Verkhne-Urushtenskiy massif), sp. 26		Orthoclase granite, sp. 5-a		Quartz-amphibole gabbro gneiss, sp. 954		Quartz-amphibole diorite gneiss, sp. 287	
	weight %	molecular amount	weight %	molecular amount	weight %	molecular amount	weight %	molecular amount	weight %	molecular amount	weight %	molecular amount	weight %	molecular amount
SiO_2	71.30	1187	72,91	1214	70,46	1173	71,80	1195	72,54	1208	48,76	0812	55,66	0926
TiO_2	0.34	0004	0,35	0004	0,41	0005	0,29	0004	0,19	0003	0,75	0009	0,66	0008
Al_2O_3	14.95	0146	14,36	0140	15,63	0153	15,25	0149	15,91	0156	17,16	0168	19,34	0189
Fe_2O_3	0.08	—	—	—	0,24	0001	0,36	0003	0,21	0001	0,97	0006	2,48	0016
FeO	3.51	0049	2,87	0040	3,02	0042	2,01	0028	2,15	0029	10,33	0143	5,31	0074
MnO	0.03	—	0,03	—	0,01	—	—	—	traces	—	0,15	0002	0,13	0001
MgO	1.03	0025	0,45	0011	0,50	0012	0,11	0003	0,15	0004	6,22	0154	3,32	0082
CaO	1.80	0034	1,97	0034	1,40	0025	1,47	0026	0,35	0006	8,48	0151	6,70	0120
Na_2O	5.23	0084	4,72	0076	2,59	0042	3,57	0057	2,39	0039	2,63	0042	4,14	0067
K_2O	1.66	0016	1,11	0012	3,84	0040	3,60	0038	5,20	0055	2,15	0022	1,59	0017
P_2O_5	0.05	—	0,07	—	0,11	0001	0,07	—	0,06	—	0,07	—	0,09	—
SO_3	0.09	—	0,06	—	0,22	0003	0,35	0004	0,08	—	0,07	—	0,17	0002
H_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Loss on ignition	0,35	—	0,47	—	1,12	—	1,48	—	1,14	—	1,81	—	1,26	—
Total	100,51	—	99,37	—	99,55	—	99,76	—	100,37	—	99,55	—	100,85	—

[a] Analyses were made in the chemical laboratory of the North Caucasus Geological Administration by V. Podol'skaya.

NOTE: Comma represents decimal point.

Table 3

Principal Chemical Characteristics of the Granites and Gneisses of the Main Range (after A.N. Zavaritskiy)

Sp. No.	Rock	a	c	b	s	a'	f'	m'	c'	n	φ	t	Q	$\frac{a}{c}$
2022	Leucocratic plagiogranite	12,8	2,17	8,38	76,22	17,4	35,5	18,1	—	84	—	0,3	[illegible]	5,8
1-kh	Biotite plagiogranite	11,61	2,24	5,74	80,38	41,3	45,9	12,6	—	86,3	—	0,3	[illegible]	5,1
28	Microcline granite (Verkhne-Urushtenskiy massif)	10,82	0,46	9,76	77,74	62,1	29,7	8,1	—	51,2	1,3	0,4	34,66	23,5
26	Same	12,60	1,70	6,16	79,49	60,21	36,5	3,2	—	60,0	6,5	0,3	32,13	7,4
[illegible]	Orthoclase granite	12,14	0,40	9,23	78,10	78,20	21,6	2,0	—	41,5	1,3	0,2	31,65	30,0
[illegible]	Quartz-amphibole gabbro gneiss	8,91	8,63	25,21	57,15	—	43,60	42,50	7,40	65,60	6,60	1,0	12,50	1,03
237	Quartz-amphibole diorite gneiss	11,20	7,00	19,56	62,26	—	36,40	27,80	5,10	80,00	10,80	0,8	4,90	1,70

Note: Comma represents decimal point.

The leucocratic variety of microcline granites contains pegmatite veins, and microcline granites proper contain quartz and carbonate veins with polymetallic mineralization.

The light-gray microcline granite is massive medium-grained rock with hypidomorphic texture. Plagioclase and quartz are present in almost equal amounts, but microcline is very subordinate (Table 4). Chloritized biotite is usually more abundant than muscovite.

The accessories are apatite, pale green zircon, epidote, rutile, sphene and minute, unidentifiable highly birefringent inclusions producing pleochroic halos in chlorite from 0.02 to 0.03 millimeters across. Pleochroic halos formed around zircon also occur, having radii of about 0.015 to 0.020 millimeters.

The plagioclase is twinned according to the albite, rarely Carlsbad law, and is usually albite (An_7-An_{10}), less frequently, oligoclase (An_{18}, An_{22} An_{33}).

Sometimes at the contact with microcline the plagioclase has a thin border of albite or contains myrmekitic quartz.

The microcline is metasomatic and occurs in small anhedral tabular-prismatic crystals larger than those of plagioclase (up to 2-3 millimeters). It is fresh but sometimes contains calcite and brown iron oxides in the cleavage cracks. It is usually perthitic with thin lamellae or veinlets of albite.

The plagioclase crystals included in microcline are four or five times smaller than those occurring in the groundmass.

The microcline replaces the plagioclase at the edges and penetrates into the cleavage cracks. Besides plagioclase relicts, microcline also contains rounded quartz grains and flakes of mica. It almost always shows the twinning grid, which is only rarely indistinct or completely absent. It was discovered by the author that the frequency of occurrence of a given value of 2V is directly proportional to its magnitude. Of measured values of the axial angle of microcline (-88°, -86°, -80°, -78°, -76° and -72°) the larger values occur more frequently than the smaller.

In some microcline grains there are areas of plagioclase without the grid structure (kaolinized material with tabular outlines; perthitic inclusions of plagioclase) which have smaller 2V. For example, in the fresh twinned areas of microcline the values of 2V are -88°, -86° or -76°, while in the untwinned kaolinized areas they are -76°, -68° or -62°. This is observed in alaskite and in porphyritic microcline granites.

Quartz is xenomorphic (0.5 - 2 mm grains), has wavy extinction and often replaces plagioclase. When abundant, it almost always has polygonal outlines and is the product of the hydrothermal stage of crystallization; when crushed, it occurs in hornfels-like aggregates.

The chloritized biotite is lamellar and occasionally contains narrow pleochroic flakes of relict biotite with γ = deep-brown, α = yellowish- or pale-brown. The birefringence of the biotite is 0.044; 2V is nearly 0°.

The chlorite is green and has a dirty-brown tinge due to the presence of iron oxides. Optically, it is near pennine and contains minute grains of epidote, opaque iron oxides and sagenite.

The muscovite is largely secondary; it is turbid with opaque clayey material.

According to the chemical analyses the microcline granite may be referred to the group of rocks oversaturated with alumina. The microcline granite of our region is similar to that of the Malo-Labinskiy massif [1].

The pegmatites. The thin (0.1 to 0.3 m) pegmatite veins in the leucocratic microcline granite were probably formed during the hydrothermal-pneumatolytic stage of crystallization. They are usually composed of tabular crystals of white microcline (2 to 3 cm), and less abundant quartz (0.5 cm), plagioclase 1 to 1.5 cm) and muscovite (1 to 3 cm).

The microcline is faintly perthitic, kaolinized and has a distinct grid structure (2V = -80°). The plagioclase (An_{10} - An_{13}) is fresh and polysynthetically twinned.

The spaces among the larger crystals of the different minerals are occupied by the smaller crystals of the same minerals. At contacts with microcline, plagioclase contains myrmekitic quartz. Occasionally idiomorphic crystals (0.3 to 0.5 mm) of colorless garnet containing quartz and sericite in the fractures are found.

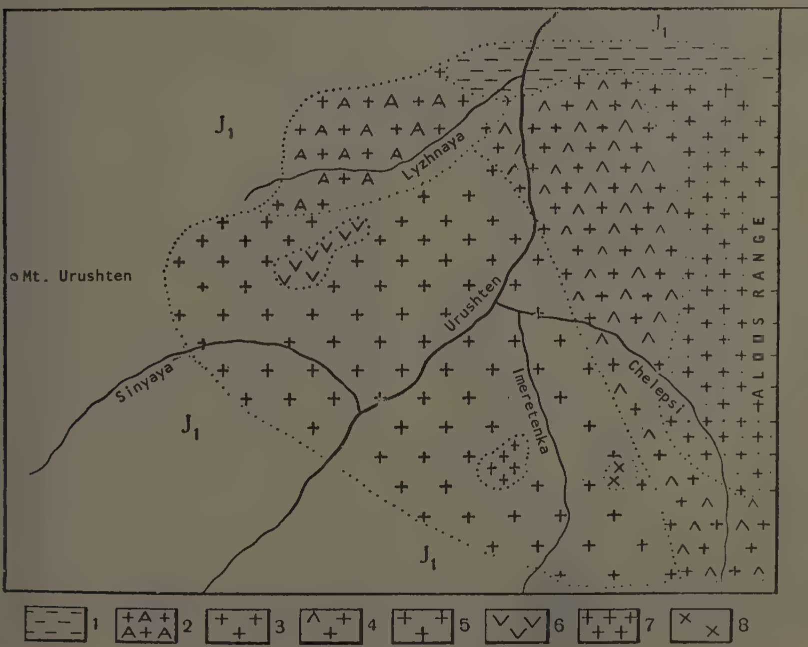

FIGURE 2. Petrographic map of the Verkhne-Urushtenskiy granitoid massif.

1 -- Precambrian-Paleozoic schists; 2 -- alaskite; 3 -- microcline granite; 4 -- leucocratic microcline granite; 5 -- porphyritic microcline granite; 6 -- quartz diorite; 7 -- biotite granodiorite; 8 -- orthoclase granite.

Table 4

Modes of the Granitoids of Verkhne-Urushtenskiy Massif (volume %)

Minerals	Microcline granites			Leucocratic microcline granite, average of 4 specimens	Porphyritic microcline granite, average of 3 specimens	Granodiorite from contact of leucocratic and porphyritic granites, specimen 1714	Alaskite, average of 4 specimens	Orthoclase granite, specimen 5-a	Biotite granodiorite, specimen 1195	Amphibole quartz diorite, specimen C-2	Biotite-amphibole quartz diorite, specimen 1669	Granodiorite from contact zone of quartz diorite and microcline granite, specimen C-3
	Average of 16 sp.	Average of 7 sp.	specimen 1									
Plagioclase	35,3	40,6	53,6	33,77	40,2	50,0	27,19	28,8	65,7	51,8	59,40	67,1
Potash-soda feldspar	25,4	14,0	5,1	20,00	25,6	1,4	22,50	31,7	rare	rare	rare	5,7
Quartz	33,4	37,0	29,8	36,16	27,8	29,8	44,03	33,8	17,6	14,5	13,24	14,0
Chloritized biotite	3,3	4,3	9,8 (with calcite)	2,53	6,0	17,1 (with epidote)	0,06	3,3	14,5 (not chloritized)	—	8,54 (not chloritized)	12,8
Muscovite	2,0	3,3	0,8	5,45	—	0,6	4,46	2,4	1,7	—	—	—
Amphibole	—	—	—	—	—	—	—	—	—	29,6	15,45	—
Secondary minerals	—	—	—	—	—	—	—	—	—	3,6	3,04	—
Ore and accessory min.	0,6	0,8	0,9	2,09	0,4	1,1	1,76	—	0,5	0,5	0,33	0,4 (with epidote)
Total	100,0	100,0	100,0	100,00	100,0	100,0	100,00	100,0	100,0	100,0	100,00	100,0

Note: Comma represents decimal point.

Porphyritic microcline granite is gray, medium-grained rock with numerous tabular crystals of microcline (2 to 4 cm). Minute flakes of chloritized biotite are visible in the microcline. The rock is porphyritic with hypidiomorphic groundmass. The plagioclase is the dominant mineral, the amounts of quartz and microcline are about the same and the accessory minerals are apatite and zircon; the latter is surrounded in chlorite by pleochroic halos 0.020 millimeters in radius.

Plagioclase (An_{18} - An_{19}) is always sericitized in the center, weakly zoned and often rimmed with fresh albite. The plagioclase laths are 1.5 to 2 millimeters in length, seldom 3.5 mm. At contacts with microcline, the plagioclase sometimes contains myrmekitic quartz.

The chloritized biotite is strongly pleochroic from dark-brown to light-brown (α); $\gamma - \alpha = 0.054$. The chlorite is pleochroic from light-green to yellow (α) and is near pennine in composition. It contains minute grains of epidote and opaque oxides.

At the contacts with leucocratic microcline granite, the porphyritic granite changes to dark-gray granodiorite with blastogranitic texture. The granodiorite contains almost three times as much chloritized biotite as porphyritic granite, no microcline and a more calcic plagioclase (An_{29} instead of An_{18}).

Alaskite. A small alaskite massif is exposed on the Lyzhnaya River, the left tributary of the Urushten. The alaskite has an intrusive contact with the crystalline Urushten substratum. The two-mica schists at the contact with the alaskites are plicated and injected with granite. Besides the primary minerals (granoblastic quartz, muscovite, biotite, plagioclase) they contain chloritized biotite, quartz-muscovite, micropegmatite, and metasomatic microcline with poorly developed grid structure. In the zone of contact with the crystalline substratum the alaskite is medium-grained, porphyritic and has hypidiomorphic groundmass. The secondary (calcite and brown iron oxides) and accessory minerals (apatite, rutile, zircon, pyrite) are scarce.

The orthoclase granite is light-gray and coarse-grained. It has hypidiomorphic texture and is composed of orthoclase, plagioclase, quartz and a small amount of muscovite and chloritized biotite. The accessory mineral is metamict zircon surrounded in chlorite by sharp pleochroic halos with a radius of about 24 millimeters.

The orthoclase with $2V = -62°$; $\beta \perp (001) = 1 - 7°$ occurs in more or less euhedral crystals (3 to 6 mm). It replaces plagioclase. Chemically orthoclase granite differs from microcline granite mainly in having a higher potassium and a lower calcium content.

The biotite granodiorite is fresh as compared with the other granitoids of the Verkhne-Urushtenskiy massif. It is gray, medium-grained and massive.

Its texture is hypidiomorphic, and its essential minerals are plagioclase (An_{32}), quartz, biotite, a small amount of muscovite and occasional crystals of orthoclase. Apatite and zircon are the accessories.

On the Imeretenka River, near the exposure of biotite granodiorite, there is an outcrop of pegmatoidal albite granite. It is composed of albite laths (An_6, An_7) up to 2-3 centimeters in length, slightly deformed muscovite crystals (1 to 1.5 cm) and quartz grains (1 to 5 mm) with faintly wavy extinction. It is interesting that the albite usually contains a few small grains (0.1 to 0.3 mm) of kaolinized microcline with grid structure.

It is possible that this granitoid was formed as a hybrid contact during the intrusion of biotite granodiorite.

The quartz diorite occurs in two varieties, the coarse-grained, containing amphibole, and the medium-grained, containing biotite and amphibole. The former constitutes the main mass of the quartz diorite outcrop and the latter, its margins. In some cases the contact zone between diorite and microcline granite is occupied by coarse-grained granodiorite.

The amphibole quartz diorite is gray, massive and contains slender prismatic hornblende crystals 3 to 6 mm long. The biotite-amphibole quartz diorite is a dark-gray massive rock with grains of biotite and hornblende averaging 2 millimeters in length. Microscopically the two varieties are similar; both have hypidiomorphic, occasionally monzonitic texture. The modes of these rocks are given in Table 4. Their accessory minerals are apatite, zircon, magnetite, sphene and hematite.

The plagioclase (An_{33} - An_{37}) occurs in tablets (0.5 to 1 mm) and is strongly sericitized, zoned and often fractured. The anhedral grains of quartz (0.5 to 2 mm) have wavy extinction and are always fractured. The amphibole is a common hornblende pleochroic from green (γ) to deep yellow-green (β) and yellowish (α); $c{:}\gamma = 21°$, $2V = -70°$; and $\gamma - \alpha = 0.024$.

The amphibole is slightly replaced by chlorite of the pennine type and contains abundant inclusions of epidote in the form of colorless oval grains elongated parallel to cleavage.

Table 5

Optical Constants of Potash-Soda Feldspars
from the Granitoids of the Pereval'naya Subzone in the Verkhne-Urushtenskiy Massif

Specimen Number	Rock	2V	(001)			Remarks
			α	β	γ	
2020	Leucocratic plagiogranite	-64°	-	-	-	Grid very poor (diffuse); fresh
		-70°	-	-	-	
1608-a	Melanocratic biotite plagiogranite	-88°	-	-	-	Same
1654-c	Tonalite	-66°	90°	26°	64°	Probably (001) edge of orthoclase
		-70°	86°	26°	64°	Brown, no grid
7-oz	Microcline granite	-76°	83°	11°	82°	Lattice, no grid; fresh surface
		-72°	78°	12°	88°	
		-86°	-	-	-	
		-82°	-	-	-	
Gr-Sr	" "	-78°	80°	14°	80°	Same
		-86°	83°	14°	77°	
		-82°	83°	10°	82°	
2808	Granodiorite	-64°	78°	12°	83°	Same
		-80°	-	-	-	
5-gr	Leucocratic horizon	-78°	80°	20°	72°	(001) edge; no grid; brown
1174	Microcline granite	-82°	87°	9°	83°	Grid unclear; fresh
1198-a	" "	-88°	83°	11°	87°	Good grid; fresh
1208	" "	-69°	89°	7°	90°	Grid very poor; fresh
1212	" "	-60°	90°	0°	90°	No grid; fresh
1215	" "	-66°	87°	6°	86°	Same
1229-a	" "	-60°	75°	18°	81°	Grid very poor; fresh
1648-b	" "	-86°	80°	72°	20°	⊥(110) Good grid; fresh
1671	" "	-82°	74°	16°	86°	Same
1680	" "	-82°	81°	12°	83°	Grid unclear, fresh
1719-a	Leucocratic microcline granite	-74°	76°	16°	83°	No grid; fresh
1727-b	Porphyritic microcline granite	-88°	12°	88°	78°	Fresh area with grid ⊥ (130).
		-72°	10°	80°	88°	No grid; kaolinized area
146	Alaskite	-80°	84°	7°	87°	No grid; fresh
5	Orthoclase granite	-66°	86°	7°	84°	Same
		-62°	90°	0°	90°	
1195	Biotite granodiorite	-66°	90°	0°	90°	Same
		-70°	-	-	-	
S-Z	Granodiorite from contact zone between quartz diorite and microcline granite	-80°	77°	18°	77°	Grid very poor; fresh
		-70°	73°	13°	84°	

The biotite is usually developed at the expense of the hornblende but in the biotite-amphibole quartz diorite it occurs as independent crystals. It is pleochroic from brown (γ) to light-brown (α); 2V is nearly zero and $\gamma - \alpha = 0.0647$.

The coarse-grained granodiorite occurs in the contact zone between quartz diorite and microcline granite and is composed of large (up to 1 cm) plates of black chloritized biotite, laths of light-gray plagioclase and pink microcline (2 to 5 mm).

The microscope shows that the rock has monzonitic texture, sharply idiomorphic plagioclase crystals and xenomorphic grains of other light-colored minerals.

The curved plates of chloritized biotite are wrapped around plagioclase crystals. The plagioclase is strongly sericitized and is near albite-oligoclase in composition. Quartz has wavy extinction and biotite is completely

replaced by chlorite (pennine) pleochroic from green to almost colorless, yellowish (α). The axial angle of chlorite is -20°; dispersion $\underline{r} > \underline{v}$. Microcline with poorly developed twinning is slightly kaolinized. Idiomorphic crystals of apatite (up to 0.2 mm) are abundant.

SUMMARY
OF THE VERKHNE-USHTENSKIY
GRANITOID MASSIF

The complex structure of this massif reflects polyphase emplacement. The author believes that quartz diorite, biotite granodiorite and orthoclase granite are the youngest rocks of the massif. The main reasons for this conclusion are:

1) the fresh aspect of these rocks as compared with the surrounding microcline granite;

2) the absence of evidence that these rocks are xenoliths;

3) the fact that several investigators (I.I. Bessonov [4], I.Ya. Baranov [2] and G.P. Chkhouta [9]) regard similar granitoids from the eastern regions as being the youngest among the Hercynian intrusions of the Main Range.

As has already been mentioned, the Verkhne-Urushtenskiy granitoid massif is a continuation of the Malo-Labinskiy massif in which, according to Afanas'yev, the porphyritic microcline granite was formed by contamination of the magma (by amphibolites and other rocks of the substratum of the Urushtenskiy complex) which produced the nonpolphyritic microcline granite. The alaskite Afanas'yev regards as a product of the same magma, but belonging to a different, younger phase of crystallization.

This scheme of formation of the granitoids is applicable to the Verkhne-Urushtenskiy complex investigated by the author.

SUMMARY

The author's investigations provide new material on the granitoids of a difficultly accessible part of the Main Range of Western Caucasus and a more exact knowledge of the relationships between the Lower Carboniferous deposits, the rocks of the ancient substratum and the individual intrusions of the granitoid complex of the Main Range; i.e. they extend the work of G.D. Afanas'yev [1].

The author's investigations have shown that in the west, from the upper waters of the Malaya Laba River to the sources of the Kisha River, in the Pereval'naya subzone of the Main Range of Western Caucasus, there are exposures of various, mainly plagioclase-rich granitoids containing dikes and amphibole gneisses belonging to the Urushtenskiy complex. The varieties of microcline granite of the Pereval'naya subzone, as well as the complex Verkhne-Urushtenskiy massif, were formed, apparently, synchronously in Hercynian time and are a part of the Main Range granitoid complex.

REFERENCES

1. Afanas'yev, G.D., GRANITOIDY DREVNIKH INTRUZIVNYKH KOMPLEKSOV SEVERO-ZAPADNOGO KAVKAZA [GRANITOIDS OF THE ANCIENT INTRUSIVE COMPLEXES OF NORTHWESTERN CAUCASUS]: Tr. In-ta geol. nauk Akademiya Nauk SSSR, vyp. 69. petrogr. ser. (no. 38), 1950.

2. Barabanov, I.Ya., .GRANODIORITY VERKHOV'YEV BOL'SHOY LABY NA SEVERNOM KAVKAZE [GRANODIORITES OF THE UPPER WATERS OF THE BOL'SHAYA LABA RIVER IN NORTHERN CAUCASUS]: Uch. zap. Rostovsk. n/D un-ta, t. 10, spets. vyp., 1937.

3. Baranov, I.Ya., NEKOTORYYE DANNYYE PO VOPROSU O GENEZISE, RASCHLENENII I GEOLOGICHESKOM POLOZHENII GRANITOV GLAVNOGO I PEREDOVOGO KHREBTOV SEVERO-ZAPADNOGO KAVKAZA [DATA ON THE GENESIS, SUBDIVISION AND GEOLOGICAL POSITION OF GRANITES OF THE MAIN AND FRONT RANGES OF NORTHWESTERN CAUCASUS]: Uch. zap. Rostovsk. n/D un-ta, t. 23, vyp. 23, 1954.

4. Bessonov, I.I., GEOLOGICHESKOYE STROYENIYE OBLASTI VERKHOV'YEV R. BOL'SHOY LABY (ZAPADNYY KARACHAY) [GEOLOGICAL STRUCTURE OF THE UPPER REACHES OF THE BOL'SHAYA LABA RIVER (WESTERN KARACHAY)]: Tr. po geol. i polezn. iskop. Sev Kavkaza, sb. 2. Rostov n/D, 1938.

5. Vardanyants, L.A., MATERIALY PO PERTROGRAFII SEVERO-ZAPADNOGO KAVKAZA [MATERIALS ON THE PETROGRAPHY OF NORTHWESTERN CAUCASUS]: Tr. Azovo-Chernomorsk. geol. tresta, vyp. 11, 1935.

6. Eremeyev, V.P., K VOPROSU O

KHARAKTERE KONTAKTOVYKH IZMENENIY GLINISTYKH SLANTSEV. V KN. VOPROSY MINERALOGII I PETROGRAFII T.I [THE CHARACTER OF CONTACT METAMORPHISM OF SHALES. IN THE BOOK: PROBLEMS OF MINERALOGY AND PETROGRAPHY, V. 1]: Akademiya Nauk SSSR, 1953.

7. Kobilev, A.G., PALEOINTRUZII I NEO-INTRUZII AZOVO-CHERNOMOR'YA [OLD AND YOUNG INTRUSIVES OF THE AZOV-BLACK SEA REGION]: Materialy Azovo-Chernomorsk. geol. upr. po geol. i polezn. iskop., sb. 3, 1938.

8. Lyakhovich, V.V., OB ODNOY OSOBENNOSTI KONTAKTA GRANITA S ROGOVIKAME (SEVERNYYI KAVKAZ) [ON A PECULIAR FEATURE OF CONTACT BETWEEN GRANIT AND HORNFELS (NORTHERN CAUCASUS)]: V. kn. vopr. mineralogii i petrografii, t. 1, Akademiya Nauk SSSR, 1953.

9. Chkhouta, G.R., INTRUZIVY ABKHAZII [INTRUSIVES OF ABKHAZIYA]: Tr. Gruz. geol. upr., vyp. 2, 1941.

Rostov on the Don
University

Received April 16, 1958

THE MAJOR STRUCTURES OF THE URALS AND THEIR ORIGIN[1]

by

A. A. Pronin

The literature on the tectonics of the Urals is not extensive, partly because of the complexity of the geologic structure of the ranges and partly, and this is perhaps the main reason, because of the slow development of tectonics as an independent science as compared, for example, with the development of stratigraphy and petrography. Even the explanatory notes accompanying the compiled geological maps of the Urals lack chapters dealing with the tectonics of the range.

The present paper is a discussion of some of the tectonic problems of the Urals, mainly of their central and southern parts, based on the author's own investigations carried on for many years, and other abundant unpublished material.

These problems include: the number of structural or tectonic-stratigraphic levels in the rocks of the Urals, the characteristics of the plication and disjunctive tectonics of these levels, the subdivision of the Urals into geotectonic regions, the role of deep fractures, the phenomenon of regeneration in the development of the principal structures, the conditions of formation and the main stages of development of these structures, etc. In the discussions of these problems by previous investigators, a general tendency is apparent to assign an extremely large role in forming the present aspect of the Uralian folded structure to the middle and upper Paleozoic tectonic and magmatic processes and to underestimate the significance of the events of the earlier periods in the development of the Uralian geosyncline.

Until the early 1930's, most geologists believed that the folded structure of the Urals was formed during a single stage of tectonic movement and magmatic activity, the Variscan orogeny. Today, no one denies that an important role in the formation of the Urals was played also by tectonic and magmatic stages before the Variscan. However, the relative significance of Paleozoic sedimentation, volcanism, plutonism and tectonic movements in forming the structural plan of the Urals, and of the same processes during the Precambrian stage of development of the Uralian geosyncline, has not been established.

In the present work evidence is cited indicating that the primary role in the formation of the Urals was played, not by Paleozoic, but by Precambrian geological processes, which laid the foundation and general structural plan of the modern Urals. During the Paleozoic this plan varied slightly but basically remained unchanged. In the geological section of the Urals the ancient basement plays a more important role than the Paleozoic structural level, which forms a relatively thin and discontinuous layer in the general rock complex of the Urals.

To provide a basis for these ideas of the relative significance of the Paleozoic and Precambrian rocks in the structure of the Urals, the main points of the Uralian tectonics will be reviewed.

THE MAIN STRUCTURAL LEVELS AND THEIR TECTONIC CHARACTERISTICS

The existing geological knowledge of the Urals permits separation of their strata into four structural levels corresponding to four stages in the history of the development of the Uralian geosyncline: Archean, Proterozoic (Riphean), Paleozoic and lower Mesozoic. The horizontal upper Mesozoic and Cenozoic strata of the region adjacent to the Urals in the east (Zaural'e) form a fifth structural level, but they are platform deposits and will not be discussed here. Each structural level is separated from the next by a series of disconformities and angular unconformities and is divided into a group of structural levels of the second order, or sublevels, with the same stratigraphic relationships as in the main

[1]Osnovnyye tektonicheskiye struktury urala i ikh proiskhozhdeniya.

levels and with approximately the same structure: the lower part consists mainly of basic volcanic rocks and small intrusives of the same composition, the middle part contains about equal amounts of volcanic and sedimentary rocks, and the upper part is predominantly sedimentary. The formation of the three pre-Mesozoic levels culminated in the emplacement of plutonic rocks of different composition, folding and faulting. Corresponding to the number of structural levels, it is necessary to distinguish in the rocks of the Urals four main systems of folds and faults of different ages, each of which is divisible into systems of the second order corresponding to the structural sublevels.

A general description of the structure of each of the levels is given below.

1. The Archean structural level. The rocks of this level are exposed as brachyanticlines over relatively small areas, and their stratigraphy and tectonics are complex. This level is composed of strongly metamorphosed sedimentary and igneous rocks represented by biotite, garnet-biotite and garnet-sillimanite-biotite gneisses, sometimes with augen structure, and by micaceous and ferruginous (magnetite) quartzites, schists, phyllites and marbles. Besides the metamorphics, there are granites, granite gneisses, gabbroids, amphibolites, and ultrabasic rocks. Absolute age determination of the potash feldspars from the paragneisses by the argon method gave 1,050, 1,090 and 1,150 million years, and the sedimentary rocks from which the gneisses were formed must, therefore, be much older. The potash feldspars from the granites date from 1,165 million years, and the potash feldspars from fragments of lower Paleozoic and upper Riphean arkosic sandstones, which lie unconformably on Archean rocks both on the western and the eastern slope, date from 1,600 to 2,300 million years. The discrepancy in the ages of the potash feldspars from the arkosic sandstones and from granites and gneisses indicates that the potash feldspars from the granites and gneisses were rejuvenated by the upper Archean or Riphean metamorphism and metasomatism. The exposed thickness of the rocks in this level is 5,000 meters.

The internal tectonics of this structural level is very complex and varied: in places the metamorphics form extensive low brachyanticlines, in other places complex elongated folds are further complicated by small tight plications, boudinage, etc.

2. The Proterozoic (Riphean) level. This level consists in its lower part mainly of basic volcanics and synchronous small gabbroid intrusives. In many places, especially on the eastern slope of the Urals, these rocks have been changed to amphibolites. In the middle and upper parts of the level, sedimentary rocks predominate, represented mainly by graphitic phyllites and quartzitic schists but also by quartzites, argillaceous shales, amphibolites and marbles.

The wide distribution of graphitic phyllites and quartzites among the rocks of the Riphean structural level is a very characteristic feature and permits correlation of Riphean rocks in all tectonic belts and in the remote parts of the Urals.

Besides sedimentary rocks, there are widespread plutonic igneous rocks. The age of the Berdyaush granites, formed during one of the upper Riphean magmatic phases, is 990 million years; the age of granite gneisses from the vicinity of the village of Naslednin-skoe on the eastern slope of the Southern Urals is 500 million years.

The Archean and Proterozoic (Riphean) structural levels on the western slope of the Urals and the region of the divide are separated by disconformities and angular unconformities into four sublevels, which have been distinguished, so far, only in the region of the Bashkir-Uraltaus upwarp. On the eastern slope there are no clear indications of stratigraphic break or angular unconformity between levels.

The most characteristic feature of the Proterozoic structural level is gently folding, represented by extensive brachyanticlines of three kinds:

a) symmetrical, with gently dipping (10°-40°) limbs with wave-like plications, along both strike and dip;

b) asymmetrical, overturned to the west, usually with gently dipping, plicated eastern limbs and steep, sometimes overturned western limbs;

c) imbricate, formed, apparently, by faulting of the western limbs of overturned anticlines of the preceding type.

The gentle folding and the presence of graphitic phyllites and quartzitic schists makes it possible to distinguish Proterozoic sequences with certainty from similar Paleozoic sequences. The thickness of the Proterozoic strata is approximately 8,000 to 12,000 meters.

3. The Paleozoic structural level. The Paleozoic structural level is separated from the Proterozoic by a series of stratigraphic breaks and angular unconformities. On the western slope it consists of sedimentary rocks; on the eastern, of continental deposits and tuffaceous rocks in the lower part, mainly of

volcanic rocks in the middle part (Gotlandian-Middle Devonian) and mainly of sedimentary rocks in the upper part (Upper Devonian-Permian). Associated with the volcanic rocks are widespread plutonic igneous rocks of different ages, largely of basic and ultrabasic composition. Disconformities and angular unconformities divide this structural level into no less than eight sublevels, which include rocks of the following ages: a) lower Paleozoic, b) Upper Ordovician-Middle Ludlovian, c) Upper Ludlovian-Lower Devonian, d) Eifelian, e) Givetian, f) Frasnian-Tournaisian, g) Visean-Namurian, and h) upper Paleozoic, which is divisible on the eastern slope of the Urals into a number of sublevels of the third order.

Unlike the Proterozoic (Riphean) structural level, the Paleozoic level is characterized by narrow almost isoclinal folds with limbs dipping from 45° to 90°.

The folds are tens and even hundreds of kilometers long and from a few to ten kilometers wide. They are usually overturned and broken by reverse and thrust faults.

The thickness of the Paleozoic strata is 5,000 to 10,000 meters.

4. The Lower Mesozoic level. The rocks of this level are restricted to rather narrow depressions as deep as three kilometers trending nearly due north. The lower part of the sequence is composed of basic, locally acid volcanics, and the upper, of continental, coal-bearing sediments. The lower Mesozoic level is separated from the Paleozoic level by a series of stratigraphic breaks and angular unconformities. Tectonically, this level is similar to the underlying one. The thickness of the rocks is 2,000 to 3,000 meters.

Thus, at least four principal systems of folds of different ages must be distinguished in the Urals and the same number of stages of intrusive activity, but counting the structural sublevels, the number of phases of tectonic and intrusive activity is at least twelve.

THE PRINCIPAL STRUCTURES OF THE URALS AND THEIR ORIGIN

Longitudinally, the entire folded system of the Urals is divided into a series of large upwarps and downwarps, the former being composed mainly of Precambrian rocks and the latter of Paleozoic and lower Mesozoic rocks. Each upwarp and downwarp extends for a considerable distance along the axis of the Urals, is deeply rooted in the earth's crust, has gone through a long period of development and represents an individual geotectonic regime. Within each structure are structures of the second order, anticlinoria and synclinoria, and within these are structures of the third order, anticlines and synclines.

The major structures separated by the author are, from west to east (Fig. 1):

I. Russian platform (eastern edge).

II. Western Urals downwarp.

III. The Bashkir-Uraltau upwarp.

IV. Tagil-Magnitogorsk downwarp.

V. Eastern Urals upwarp.

VI. Alapeavsk-Chelyabinsk downwarp.

VII. Kamyshlov-Troitsk upwarp.

VIII. Upper Tobol downwarp.

All upwarps are composed of gently folded Riphean strata (the Riphean structural level), locally exposed brachyanticlines of the Archean level and Paleozoic rocks lying in small depressions formed by superimposed synclines.

The three upwarps are equal in size and significance in the structure of the Urals.

The Bashkir-Uraltau upwarp, considered until recently as the axial structure of the Urals, must be regarded as an analogue of the two upwarps on the eastern slope of the Urals. It is very probable that it is precisely in these eastern upwarps that the oldest rock complexes are exposed.

The Paleozoic section in the synclines superimposed on the upwarps is very incomplete; i.e., it contains many disconformities and its stratigraphic units are much thinner than equivalent units in the downwarp sections. In many regions, Ordovician, Gotlandian, Devonian or Carboniferous strata lie unconformably on the eroded Riphean surface and this indicates, first, that whole systems are missing from the Paleozoic section in the upwarped areas, and, second, that the hypsometric position of the upwarped surfaces remained more or less stable during the entire Paleozoic era and were covered by seas for only brief intervals of time.

Each upwarp is separated from the neighboring downwarp by a series of parallel deep faults, some of which stand out clearly in the modern section of the folded Urals and others are concealed. These faults played an exceptionally large role in outlining the general geotectonic plan of the Urals, which persisted

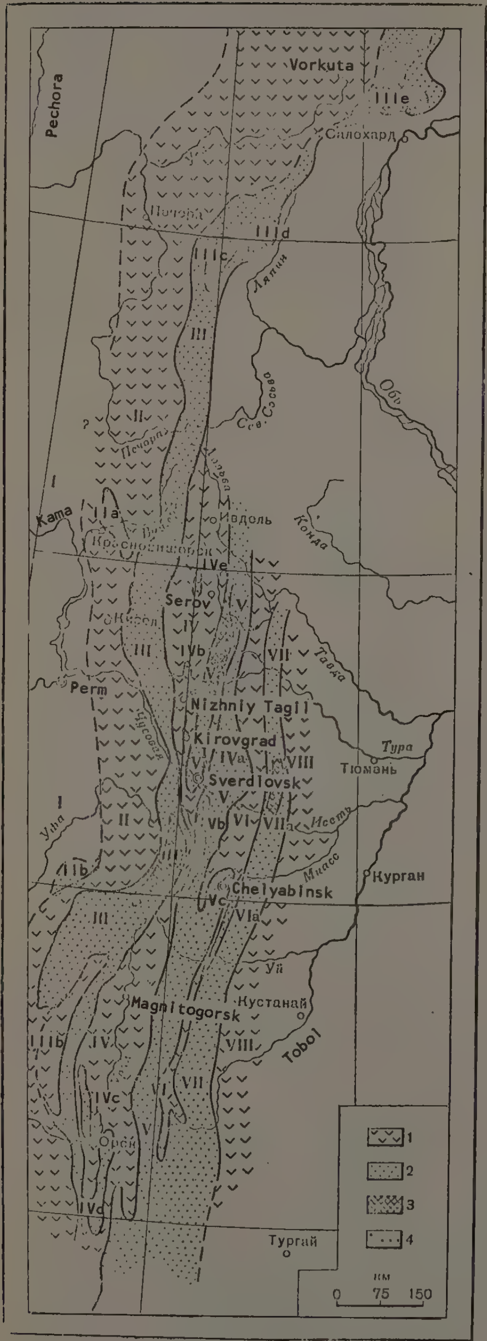

FIGURE 1. Outline of geotectonic regions of the Urals.

I -- Russian platform;

II -- West Ural downwarp;
-- a - Polyudovskiy anticlinorium;
-- b - Karataus anticlinorium;

III -- Bashkir-Uraltau upwarp;
-- a - Taratash-Ufaley anticlinorium;
-- b - Zilair synclinorium;
-- c - Lyapinskiy anticlinorium;
-- d,e - Verkhsobinskiy anticlinorium;

IV -- Tagil-Magnitogorsk downwarp;
-- a - Sverdlovsk synclinorium;
-- a,b,c,d,e - superimposed synclines filled with Lower Mesozoic coal-bearing strata;

V -- East Urals upwarp;
-- a - Saldinskiy anticlinorium;
-- b - Il'menogorskiy - Sysertskiy anticlinorium;
-- c - Chelyabinsk anticlinorium;

VI -- Alapaev-Chelyabinsk downwarp;
-- a - Chelyabinsk coal basin;

VII -- Kamyshlov-Troitsk upwarp;
-- a - Krasnogvardeyskiy anticlinorium;

VIII -- Verkhne-Tobol'sk downwarp.

1 -- Paleozoic; 2 -- Proterozoic; 3 -- Archean; 4 -- Mesozoic.

with only slight changes through the Paleozoic, Mesozoic and Cenozoic eras.

The structural depressions have the following characteristics distinguishing them from the upwarps. They are composed mainly of Paleozoic volcanic and sedimentary rocks, among which Precambrian rocks are exposed in brachyanticlines and lower Mesozoic rocks in the superimposed synclines. Their stratigraphic section is characterized by the completeness and great thickness of the stratigraphic units; the stratigraphic breaks are short, with only some horizons and parts of stages missing from the section. The thickness of the Paleozoic strata in the downwarps, as has already been mentioned, is 5,000 to 10,000 meters. Such large accumulations of sediments and volcanics is possible, evidently, only when the floor (basement) of a downwarp subsides slowly, and this is undoubtedly what happened throughout the Paleozoic era and locally through the early Mesozoic as well.

The four principal downwarps are equivalent in scale and alike in their development except for the Western Urals downwarp, which differs sharply from the rest. It is in the regions of subsidence that sedimentation, volcanism and intrusive igneous activity occurred during the Paleozoic and, on a much diminished scale, continued in the lower Mesozoic. Thus, in effect, the downwarps existed as active geotectonic elements up to and through the Jurassic period.

Deep fractures and the principle of regeneration played a tremendous role in the formation of upwarps and downwarps and of the features of geotectonic regime which distinguish them.

It was noted earlier that each upwarp is separated from the adjacent downwarp by a series of closely spaced faults. This is proved by the following:

1. The Paleozoic section in the upwarped areas is characterized by interruptions: entire systems are missing from it and, moreover, the areal distribution of the Paleozoic stratigraphic units is limited, for they were deposited in small depressions of the superimposed type. The maximum thickness of the Paleozoic strata in the upwarps is 1,500 to 2,000 meters. The change from the upwarped areas, whose modern surface is composed almost entirely of Precambrian rocks, to the downwarped areas is very sharp, occurring within a few hundred meters or a kilometer. Such rapid passage from upwarp to downwarp can be explained only by the presence of boundary faults.

2. The thickness of the Paleozoic strata in the downwarped areas is approximately the same on the periphery and in the center. This indicates that the floors of the downwarps subsided uniformly, to the same depth over the whole area. In the absence of faults, the floors would have subsided to a greater depth in the center than on the periphery.

3. The distribution of rocks characteristic of synclines with the youngest in the center and the oldest along the periphery is not observed in the downwarps. On the contrary, the youngest rocks on the surfaces exposed at present are commonly on the periphery and the oldest in the center of a downwarp. Each downwarp exhibits a great variety of facies characterizing different stages in its geological development, and numerous horizontal and vertical facies changes. Thus each downwarp, while similar to others, is a small, independent Paleozoic geosyncline, bounded by deep fractures.

4. The change from the gentle folds characteristic of the Riphean structural level which forms the upwarps to the steep, almost isoclinal Paleozoic folds occurs rapidly from west to east, within a zone less than a kilometer wide.

5. Besides these indirect indications, the presence of deep fractures on the boundaries of upwarps and downwarps is confirmed directly by the occurrence of belts of ultrabasic and gabbroid intrusions extending sometimes for hundreds of kilometers along the boundaries. An example of this is the so-called platinum-bearing gabbro-peridotite belt located near the western boundary of the Tagil-Magnitogorsk downwarp and the belt of mainly ultrabasic intrusions stretching along the eastern boundary of the same downwarp from Kirovgrad to the latitude of the town of Serov.

6. The deep fractures along the western boundaries of upwarps have developed into reverse and thrust faults and are clearly seen on geologic maps, for they bring in contact along the fault lines rocks of different ages, most frequently Precambrian and middle Paleozoic.

Deep fractures are not restricted to the boundaries of upwarps and downwarps: they dissect the basement under the Paleozoic strata into blocks and extend through some or all of the Paleozoic structural sublevels. All plutonic intrusions and the vents of Paleozoic and Mesozoic volcanoes are associated with the deep fractures.

The deep fractures played a tremendous role in the formation of the principal structures of the Urals, for throughout the Paleozoic and the early Mesozoic eras all vertical, horizontal and oblique movement of rock

masses of the upwarps and downwarps took place along them. The magmatic activity during the development of the Uralian geosyncline is also related to the deep fractures, which provided channels for the rise of magma to the surface as well as space for various plutonic rocks. The distribution of deep fractures and of the large blocks of rock which moved along them determined also the distribution of the sedimentary facies during various intervals of geologic time. It is difficult to mention any geological process which in one way or another was not dependent on the presence and activity of the fractures.

As for the phenomenon of regeneration in the development of Uralian folded structures, it may be interpreted as follows.

The principal upwarps and downwarps formed at the end of the Proterozoic continued to exist as geotectonically active elements throughout the Paleozoic and the beginning of the Mesozoic. All geological processes (sedimentation and volcanic and intrusive activity) occurred during the general subsidence of the floors of the downwarps, and the relationship between them and the upwarps was preserved. There was no complete redistribution of the main elements of the geotectonic plan of the Uralian geosyncline during the geological history of the region. The Paleozoic tectonic movements did not cause a radical reconstruction of the geotectonic plan or reversals of large structures, nor did they produce new deep fractures and redistribution of the belts of intrusions and volcanic vents. The geotectonic history of the upwarps and downwarps was not interrupted by these movements and re-initiated but continued with the preservation of the original conditions, i.e., with unchanged distribution of the principal upwarps and downwarps and persistent subsidence of the floors of the latter.

In the Paleozoic and Mesozoic of the Urals, no less than fifteen tectonic phases are recorded in the stratigraphic breaks and some of the angular unconformities; however, in most cases these were local phases, affecting individual tectonic zones or regions. They cannot be synchronized either with Stille's "universal" phases established on the basis of European studies nor with the phases of the adjacent regions of the Urals. Therefore the greatest caution must be used in separating not only the "universal" phases of these movements but even of whole orogenic stages (the Caledonian, for example).

Before passing to the history of the Uralian geosyncline and the characterization of the conditions of formation of the major structures, it is necessary to explain the relation of the folded zone of the Urals to the Russian platform.

The Russian platform consists of two clearly defined structural levels, the Precambrian crystalline basement and the Paleozoic complex. The overwhelming majority of investigators do not separate the crystalline basement in the rocks of the Urals, but regard its absence as the main distinction between the platform and the geosyncline.

The author considers that the crystalline basement can be separated in the Urals and that, just as on the Russian platform, it forms the Archean structural level. The only difference is that on the platform it is more monolithic, less broken by deep fracturing, while in the Urals it has been cut by numerous parallel fractures into narrow elongated blocks with north-south trend and then reworked by magmatic melts intruded into the fractures and by regional metamorphism.

During the formation of the crystalline basement of the Russian platform and of the lower (Archean) structural level of the Urals, the Uralian geosyncline had not yet come into existence and the basement was alike in both regions. The Uralian geosyncline was formed at the end of the Archean or the beginning of Proterozoic time by deep fracturing of the basement into parallel blocks and by their subsidence to different depths. The crystalline basement was split and subsided over a large area extending from the eastern edge of the Russian platform far to the east and including a large part of western Siberia and central Kazakhstan. The great size of the Riphean basin is indicated by the distribution and thickness of the Riphean carbonaceous quartzites and graphitic phyllites. Within the eastern part of the Russian platform, between the crystalline basement and the Paleozoic cover, the Riphean graphitic phyllites and carbonaceous quartzites are absent and the Bavlinskaya formation occupying this position is not more than 500 meters in thickness. On the western slope of the Urals the Riphean deposits thicken abruptly to 10,000 - 12,000 meters. According to M.I. Garan'[2] the carbonaceous quartzites and graphitic phyllites are found between the Proterozoic Ay formation at the base and the Avzyan formation at the top. On the eastern slope of the Urals the thickness of the Riphean deposits reaches 10,000 meters in all upwarps from the Bashkir-Uraltau in the west to the Kamyshlov-Troitsk in the east.

The deposition of the Riphean sequence, as was mentioned above, began with the extrusion of lavas from the fractures newly formed in

[2]M.I. Garan', Age and environment of deposition of the ancient formations of the western slope of the southern Urals, Gosgeolizdat, 1946.

the Archean basement and the intrusion into them of small gabbroid and ultrabasic plutons. On the western slope of the Urals these lavas are preserved almost unchanged, while on the eastern slope they are altered together with the gabbroids into amphibolites. The formation of the Riphean level ended in regeneration of activity along the deep fractures. The entire Riphean sequence was cut by them into folded low brachyanticlines and broken by faults into large blocks elongated to the north. Later the tectonic development of the blocks became individualized; some of them retained their elevation and became upwarps, others subsided and formed downwarps. Thus the extensive Proterozoic basin up to 2,000 kilometers wide was divided into a series of narrow local geosynclines and geanticlines, each of which possessed its own individual features during the Paleozoic.

In fact, there was no single Uralian geosyncline during the Paleozoic but a series of narrow subsiding geosynclinal troughs and geanticlinal uplifts, and the regime of the latter, in many respects, was more like that of platforms than geosynclines. For example, in the region of the upwarps the interrupted, incomplete Paleozoic section is more similar to the section of the Russian platform than to the continuous and very thick Paleozoic sections of the neighboring subsided tracts.

Actually the formation of the Paleozoic structural level took place only in the four downwarps mentioned above and culminated in the folding of the Paleozoic deposits into rather complex folds and in the emplacement of large basic and ultrabasic plutons localized in the deep fractures differing in origin, in those separating upwarps and downwarps and in those which were formed in the crystalline floors of the downwarps as a result of its deformation under the pressure of adjacent upwarped blocks and of the entire Paleozoic sequence many kilometers thick.

The Paleozoic strata were folded by tectonic movements occurring throughout the entire ꞁaleozoic era. The complexity and intensity of folding were due to the presence, side by side with the downwarps, of rigid consolidated masses of the upwarps serving as the jaws of a vise during the crumpling of the Paleozoic strata. It was mentioned above that no inversion is observed in the tectonics of Paleozoic strata, but that the structures of each successive tectonic phase were inherited from those of the preceding phase. This phenomenon was due to the almost continuous subsidence of the floors of the downwarps.

The lower Mesozoic level was also formed in individual downwarps of the Paleozoic structural level, bounded, like the Paleozoic downwarps, by deep fractures. These downwarps reach several hundred kilometers in length, as for example the Chelyabinsk coal basin, and 15 to 20 kilometers in width. In this they differ sharply from the great downwarps of the Paleozoic time. The Mesozoic downwarps were local, relict geosynclines which ceased to exist in the Cretaceous period.

Thus the Uralian geosyncline initiated at the end of the Archean or the beginning of Proterozoic time developed during the Riphean into a large Uralo-Siberian basin. At the end of the Riphean it was divided into a series of local geanticlines and geosynclines and the latter, continually decreasing in size throughout Paleozoic and Lower Mesozoic time, ceased to exist by the beginning of the Cretaceous period. It is at this time that the platform regime became established in the Urals.

SUMMARY

1. In order to understand the present structure of the Urals and the main characteristics of the development of the processes of sedimentation, volcanism and tectonism, it is necessary to separate within the complex of rocks composing the Urals four principal structural levels and four noncontemporaneous systems of folding separated by stratigraphic breaks and angular unconformities.

2. The lowest level (Archean) may be regarded as the crystalline foundation for the overlying levels and as being identical with the crystalline basement of the Russian platform, but intensively fractured into blocks by abyssal fractures.

3. In plan the Uralian folded zone may be divided into a series of upwarps and downwarps bounded by deep fracture zones. These structures originated in the extensive Uralo-Siberian basin at the end of the Riphean time and continued to exist until the end of the Jurassic period.

4. A prominent role in the formation of the present tectonic aspect of the Urals was played by deep fractures and by the phenomenon of regeneration, which influenced sedimentation, volcanism, intrusive activity and the formation of structures.

Mining and Geological Institute
of the Urals Affiliate
of the Academy of Sciences, U.S.S.R.
Sverdlovsk

Received November 24, 1958

ON THE SEPARATION OF THE MAMYT FORMATION IN THE CONTINENTAL JURASSIC DEPOSITS OF THE EASTERN SLOPE OF THE SOUTHERN URALS[1]

by

Z. A. Malyutina

Continental Jurassic deposits are widespread on the eastern slope of the southern Urals between 50°12' and 52°51' N latitude and 58°0' and 59°10' E longitude. In the literature this distinctive region is known as the Orsk Urals. It stretches in a broad band in the direction of the ancient folded structures of the Urals covering the entire extreme southeastern part of the Bashkir ASSR (Khaybulinskiy region), the eastern part of the Orenburg district (Orsk, Khalilovo and Dombarovskiy regions) and the extreme northwestern part of the Aktyubinsk district of the Kazakh SSR (Kos-Istek and Stepnoy regions).

The Mesozoic-Cenozoic continental deposits, of the Orsk Urals including the Jurassic, are restricted to the downwarped part of the Paleozoic folded basement. According to Belousov's classification of geologic structures, this downwarp may be regarded as belonging to the interior basin type formed at the final stage of uplift of a geosyncline.

The interior basin of the Orsk Urals is located in the southern plunge of the Magnitogorsk synclinorium and includes a number of its zones complicated by the tectonic movements which caused the formation of several basins. At present I distinguish six such basins in the Orsk Urals: the Baymak, the Priirendyk, the Akkeramn, the Alimbetov, the Orsk and the Donsk.

The western boundary of the interior basin of the Orsk Urals is the Ural Tau anticlinorium (Fig. 1); and the eastern, the East Urals or Mugodzhar anticlinorium. The part of the Magnitogorsk synclinorium lying between these boundaries consists of a number of structures of the second order, anticlines and synclines, intensely complicated by the same tectonic movements which produced these positive and negative structures.

The geological structure of the region is very complex and still little known, although there are geological maps on 1:500,000 and for some areas on 1:200,000 and 1:100,000 scale and larger. Two structural levels are clearly revealed by these maps: the Precambrian-Paleozoic and the Mesozoic-Cenozoic.

The first structural level consists of a strongly dislocated rock complex composed of crystalline rocks represented by intensively metamorphosed cataclastic granites, granite gneisses and schists and strongly cemented sedimentary rocks. The rocks range from the Precambrian and Lower Paleozoic (Cambrian, Ordovician, Silurian and Devonian) to the Upper Paleozoic including the Upper Carboniferous. No Permian rocks have been found in the Orsk Urals. A long period of erosion is postulated and confirmed by the existence of an ancient weathered mantle on the Paleozoic basement.

The Paleozoic structures were formed under a geosynclinal regime and passed through all stages of development including uplift, dislocation, block faulting and peneplanation. As a result of complex geotectonic transformations, a very characteristic ancient relief with linear positive and negative structures was in existence at the beginning of the formation of the second structural level. The trend of these structures is the general trend of Uralian folding, in which north-south elongation of the structure is the most persistent and was for a long time inherited by successive structural levels.

The interior basin of the Orsk Urals is an inherited and superimposed structure on the eastern slope of the South Urals in the region of maximum Upper Paleozoic downwarping. That the structure is inherited is evident from the general distribution of folds, from the direction of movement of individual areas of the Paleozoic basement and from the strike of the faults, which most frequently follow the old fault lines. Naturally the boundaries of the Paleozoic and Mesozoic basins and upwarps do not coincide exactly in spite of the

---

[1]K voprosu o vydelenii mamytskoy svity v kontinental'nykh yurskikh otlozheniyakh vostochnogo sklona yuzhnogo urala.

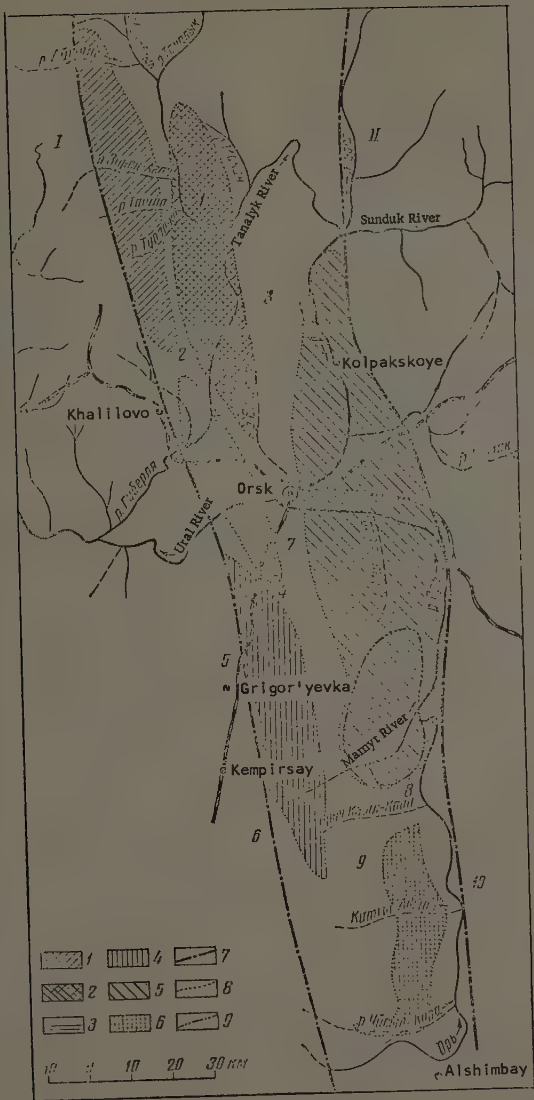

FIGURE 1. Sketch map of the distribution of basins in the interior downwarp of the Orsk Urals.

Basins: 1 -- Baymak; 2 -- Prilrendyk, 3 -- Akkerman, 4 -- Alimbetov; 5 -- Orsk; 6 -- Donsk; 7 -- outline of the inner downwarp; 8 -- outlines of basins; 9 -- outline of the South-Urals lignite deposit, Upwarps (figures on the map): 1 -- Ak''yar uplift; 2 -- Ikshininogayev ridge; 3 -- Irendyk Range; 4 -- Sanasapsko-Khabarninskiy massif; 5 -- Ebeytinsk anticline; 6 -- Kempirsaysko-Donskoy massif; 7 -- Katyn-Adyr ridge; 8 -- Kzyl-Kain uplift; I -- Ural-Taus anticlinorium; II -- Uralo-Tobol'sk anticlinorium.

close genetic relationship between them, for the younger structures were shaped by other, later crustal movements.

The interior basin of the Orsk Urals began to fill with sediments at the end of the Lower Jurassic, if the ancient weathered mantle, whose age is still problematic, is disregarded. The age of the varicolored rocks filling the deeper parts of the Orsk basin is also undetermined. They consist of redeposited materials of the ancient weathered mantle and occasionally contain plant remains of Lower Jurassic and Triassic aspect. They may be tentatively referred to the upper part of the Rhaetic-Liassic section.

The ancient weathered mantle, the redeposited varicolored rocks and the eroded surface of the Paleozoic basement itself are overlain mainly by Middle Jurassic deposits whose age, according to their megascopic flora and the spore-pollen assemblage, ranges from the Aalenian to the upper Bathonian.

The continental Jurassic deposits in the northern part of the Orsk interior basin, defined by the geographic coordinates 51°45' - 52°15' N latitude and 57°30' – 58°30' E longitude, were studied in 1932-1934 by A.L. Yanhshinskiy and P.L. Bezrukov [4] in connection with search for phosphorite and by a group of geologists of the Central Geological Exploration Institute under the direction of N.K. Razumovskiy, who mapped the Orsk Urals on 1:100,000 scale in 1935.

The first stratigraphic subdivision of the continental Jurassic deposits of the northern part of the Orsk Urals (in the Priiredndyk basin) was made by A.L. Yanshin, who separated two units — the lower, Khaybulino formation and the upper, Ziren-Agach formation. As the type section for the first, Yanshin selected an outcrop of Jurassic continental beds on the left bank of the Tanalyk River near the village of Khaybulino (now Ak'yar) which gave its name to the formation. The lithology of the formation was described and its flora identified. The Ziren-Agach formation was separated by Yanshin on lithological grounds only. At that time no extensive geophysical and exploratory geological work had been done in the Orsk Urals, and the continental Jurassic section was studied mainly in outcrops. The geophysical, geological and exploratory work began in 1952 in connection with search for lignite and the discovery of the large Orsk lignite basin (Eastern Urals basin).

The maximum and minimum depths to the Paleozoic basement concealed under Mesozoic-Cenozoic cover in the interior basin were measured by geophysical methods. In checking these data by deep drilling, the structure of the interior basin of the Orsk Urals was determined and the downwarps and upwarps of the Paleozoic basement within it outlined.

According to the geophysical data the thickness of the unconsolidated sediments in the basins ranges from 25 to 450 meters. The Mesozoic-Cenozoic strata in the Orsk basin were reached by drilling at the depth of 316.5 meters (hole no. 3932). Many drillholes reached the Paleozoic basement in other basins at 25 to 125 meters, but in the Orsk basin only at 100-290 to 300-316 meters, and in its deepest parts the basement was not reached at all. The Jurassic deposits are most completely revealed in the southern and central parts of the Orsk basin, where structural traverses such as the Mamyt, East Urals-Pervomaiskiy, Orsk, Romankul' and others were made. Here many drillholes penetrated through the Mesozoic-Cenozoic deposits to the Paleozoic basement.

The study of numerous cores by many methods laid the foundation for the development of the stratigraphic section of the Jurassic deposits of the Orsk Urals.

The entire complex of Jurassic continental deposits of the Orsk interior basin, formed during a single long sedimentation cycle, was named the Orsk series by the author. The total thickness of the sediments in the series ranges from 300 to 350 meters. The series includes essentially all of the Middle Jurassic rocks. No Lower Jurassic rocks have been identified with certainty. In some localities the Middle Jurassic sediments are underlain by unfossiliferous siltstones and clays. These rocks have not been studied sufficiently, becuase drill holes do not penetrate the deepest parts of the Orsk basin as indicated by geophysical methods.

The exploratory holes of the Romankul' traverse in the Orsk basin pass through a great thickness of Middle Jurassic deposits underlain in a number of localities (hole 1931 and others) by thin-bedded varicolored clays (cream-white to red-brown and greenish-yellow) containing sparse Triassic-Jurassic plant fossils. The thickness of these clays on the Romankul' traverse (near the Romankul' River) is 14 to 15 meters. I tentatively refer these clays to the Rhaetic-Liassic time (T_3-J_1). Very probably they will be found in the deeper parts of the basin. They have not been studied in detail.

The middle Jurassic deposits of the Orsk series are divided, from base to top, into three formations: the Khaybulino (J_2^{hb}), the Mamyt (J_2^{mm}) and the Ziren-Agach (J_2^{zir}). The first and third of these formations retain the names given them by Yanshin, and the middle one, the Mamyt, was defined and

named by myself in 1955.

An analysis of the Middle Jurassic continental deposits of the Orsk interior basin shows that the sedimentation was rhythmic and that each formation corresponds to a single phase or rhythm. The Khaybulino and Mamyt formations represent two cycles of a single lacustrine mesocycle of a higher order marking a general subsidence of the interior basin of the Orsk Urals. The Ziren-Agach formation records the beginning of a new sedimentation cycle related, as was pointed out by Yanshin, to an uplift of the Paleozoic substratum in the northern part of the interior basin, between the Jurassic and Cretaceous periods.

The Khaybulino formation is the oldest of the Middle Jurassic formations of the Orsk series in the Orsk Urals and the most extensive. It lies with erosional unconformity on the Paleozoic basement, on its weathered mantle and, locally, on the varicolored rocks formed by redeposition of the ancient weathered mantle. Genetically it is a product of a transgressive sedimentation cycle, for almost everywhere at its base lies a conglomerate ranging in thickness from 0.5 to 5 meters, followed upwards in the section by alternating gray and varicolored sandstones, siltstones and claystones containing carbonized plant remains, layers of siderite and sometimes ferruginous sandstone concretions and pods of limonite. In the Orsk Urals, the Khaybulino formation contains deposits of clayey siderite and lignite. The facies composition of the formation is variable, with lacustrine beds predominating and alluvium and lacustrine-paludal sediments occurring locally. A lithological analysis of the sections of the Khaybulino formation gives the following average proportion of the typical sediments: conglomerate and sandstone — 1-2%, sand — 45-50%, siltstone — 15-20%, gray clay — 20-26%, varicolored clay — 5-7%, lignite — < 1%, siderite — 0.01%.

Evidently during the deposition of the Khaybulino formation the rate of regional subsidence was rather high, and this led to the deposition of large quantities of sands and silts. But some areas of the basin were subjected to oscillatory movements, the rate of subsidence was reduced and marshes favorable to the accumulation of coal were formed. An example of this is the southern part of the Orsk basin, where the Khaybulino formation contains coal beds of workable thickness (Pervomayskiye areas of the Eastern Urals lignite basin).

Many identifiable plant fossils have been collected from the Khaybulino formation. For example, in 1932 Bezrukov and Yanshin collected a flora from the outcrops of the Khaybulino formation which, according to L.M. Krechetovich, contains: Hausmannia df. richteri Sew., Clathopteris meniscioides Brongn., Thinnfeldia arctika Heer, Dicrodium adantopteroides Mora, Phyllocladites rotundifolia Heer, Podozamites schenki Heer, Phoenicopsis angustifolia Heer, Pagiophyllum peregrinum Lindl. et Hutt., Schizolepis moelleri Sew. From the same Jurassic outcrop on the left bank of the Tanalyk River, A.I. Ketova-Turutanova collected and determined the following plants: Coniopteris hymenophylloides Brongn., Phoenicopsis angustifolia Heer, Czekanowskia rigida Heer, Caprolites sp., Schizolepis longpedicelata Tur.-Ket., Cladophlebis haiburnensis Lindl. et Hutt., Juccites spatutatus Pryn., Phoenicopsis speciosa Heer. In 1954 R.Z. Genkina collected 1500 specimens of fossil plants from the Khaybulino sections of the Orsk basin and identified numerous species of large- and small-leaf ferns, the most abundant being: Cladophlebis haiburnensis Lindl. et Hutt., Todites roessertii Zeiler, Osmundites (Cladophlebis) sp., Coniopteris hymenophylloides Brongn., Cladophlebis denticulata Brongn., Cl. lobifolia Phill.

Other fossil plants are also abundant, for example: Equisetites ferganensis Sew., Pterophyllum acquale Brongn., Nilssonia mediana Lesk., N. acuminata Schenk., Ginkgo concinna Heer, Baiera longifolia Heer, Baiera czekanowskia Heer, Sphenobaiera angustiloba Heer, Czekanowskia rigida Heer, Pitiophyllum nordenskioldii Heer, Hausmannia buchii Andr.

The numerous spore and pollen analyses made by the author [2] show that the assemblage from the Khaybulino formation contains 34.1% spores characteristic of the Jurassic period as a whole, including 10-12% Cyathea, 8-15% Osmunda, 3.2% Lygodium, 2-4% Lycopodium, 6-8% Leiotriletes and 3.7% Chomotriletes; 1 to 4% Lower Jurassic spores (the Klukia type and others); 45% typical Middle Jurassic spores, including 32-45% Coniopteris, 0.4% Matonia, 1.4% Acrostichum, 1-3% Dipteridaceae, 1-3% Hymenophyllaceae, 1-7% Equsetaceae and occasional Gleicheniaceae and 4-6% nondiagnostic spores (Polypodiaceae and others.

In the spore-pollen spectrum of the Khaybulino formation, spores strongly predominate over pollen; they constitute 70-73% and pollen, only 27-30%. Among the spores, those of the fern of the Coniopteris type are the most abundant. The pollen of the gymnosperms constitutes 11% and includes 1-0.9% Bennetittales, 2-5% Cycadales and 5-10% Ginkgoales. The pollen of the conifers amounts to 15.9% of the total and includes 2-3% Podozamites and 5-8% Caytoniales, 5% Coniferae with two air sacs, 1-5% Podocarpus and 0.9% other pollen.

According to the spore-pollen assemblage and macroflora, the age of the Khaybulino formation is lowermost Middle Jurassic or Aalenian. In addition to the predominant Middle Jurassic forms, the sediments of the Khaybulino formation contain such forms as Hausmannia buchii Andr., Pagiphyllum peregrinum Lindl. et Hutt, and other typically Lower Jurassic plants, which can be regarded only as transitional relict forms of the lowermost part of the Middle Jurassic section (Aalenian). On the basis of these forms, Yanshin (1932) referred the Khaybulino formation to the Lower Jurassic or Liassic.

In recent years (1952-1957), Genkina collected about 1500 specimens containing plant fossils from the Jurassic continental rocks of the Orsk Urals, and, together with the data of pollen analysis, these plants identified by her show that the Lower Jurassic forms are very subordinate and that it is correct, therefore, to place the Khaybulino formation at the base of the Middle Jurassic section in the Aalenian stage.

The thickness of the Khaybulino formation is 100 to 115 meters.

The Mamyt formation was separated by me (1953-1955) in the Orsk continental series as a local stratigraphic unit in the large area of the interior basin of the Orsk Urals. The formation is extensive and thick. Its lithology and fossil flora indicate a change in climate since the deposition of the preceding formation. The Mamyt formation represents lacustrine deposition accompanied by slow subsidence. The relation among its facies is entirely different from that in the Khaybulino formation, and it has a different coal content. The Mamyt sediments belong mainly to the Lacustrine-paludal, deltaic marsh, floodplain and stagnant pool facies. Identical lacustrine-paludal facies dominate its base and its top and the sedimentary cycle during which it was formed may, therefore, be referred to a neutral or uniform type according to Strakhov and Bushinskiy's terminology.

Clay fractions predominate over sand, and silty clay alternates frequently with siltstone, coarse gray clay, carbonaceous clay and coal. Coal forms entire zones of lenses and beds of workable thickness and is an important economic resource. The principal coal deposits of the Orsk lignite basin are in the Mamyt formation.

The type section of the Mamyt formation is based on geologic sections from the Eastern Urals brown coal deposit of the Orsk basin. Drill cores from the deposit were subjected to thorough study by a variety of methods. The principal sections are in the Mamyt River basin, and in accordance with the rules of stratigraphic nomenclature the coal-bearing strata were named the Mamyt formation. The formation is widespread in the Orsk and Donsk basins but has a limited distribution in the Akkerman basin.

Lithologically the Mamyt formation is represented by gray and light-gray coarse clays ranging from slightly to very silty and passing into true silts. Interbedding of thin layers of clay and silt is common. Sand is subordinate and sandstones are negligible. Light-gray and gray micaceous slightly silty clays with carbonaceous particles ranging from dust to coarse detritus and large fragments of coal predominate in the section.

According to computations the geological sections contain 60 to 80% of this clay, 15 to 20% of silt, 10 to 12% of sand, 1 to 3% of carbonaceous clays and 1 to 4.5% of lignite (Vostochnoural'sko-Pervomayskiy and Mamyt traverses).

There are three main varieties of sand in the Mamyt formation: the white clayey quartzose sand, the gray and light-gray argillaceous and micaceous clayey sand and the brown-gray sand. In each variety the grain size ranges from fine to medium. Usually the sand is poorly sorted. The white quartzose sand is composed of quartz with occasional flakes of mica. The heavy fraction constitutes only 0.6% and contains magnetite, pyrite, zircon, tourmaline and occasional grains of garnet.

In the brownish-gray sands the light fraction constitutes up to 96% and contains 30.6% quartz, 2.0% feldspar, 0.4% muscovite, 4.6% chlorite, 2.4% carbonaceous particles and 50% brownish-gray clay. The heavy fraction constitutes 0.4% and contains magnetite, zircon, tourmaline, garnet, orthopyroxene, chlorite, sphene, biotite and occasional grains of rutile.

In the gray micaceous sands the light fraction amounts to 95-99% and includes 66.4% quartz, 2.8% muscovite, 1.1% chlorite, 19.0% carbonaceous particles and 10.7% clay minerals. The heavy fraction (1-5%) is composed mainly of magnetite (up to 62%) with subordinate amounts of muscovite, pyrite, staurolite and garnet.

The gray and light-gray silts are more abundant in the sections than the sands. They range from fine-grained (0.01 to 0.05 mm) to medium-grained (0.25 to 0.50 mm) and pass into fine-grained sands. The silts often grade from one grain-size to another and even alternate with silty clays. In the central part of the Orsk basin they form a thick uniform gray sequence of lacustrine beds.

The silts contain quartz, fragments of dark

chert, mica and carbonaceous material ranging in size from dust to detritus and blocks of lignite. The silts are often interbedded with gray clays and, less commonly, lie at the top or base of the coal beds. The silts are typical of the widespread lacustrine facies.

The clays are predominant in the sections of the Mamyt formation and are usually gray and light-gray, nearly structureless, slightly silty to silty, or flaky and with partings of carbonaceous dark-gray clays. The dark-gray clay is very subordinate in the section and usually occurs as partings in the coal beds and at their base and top. Genetically they are usually related to the marshy alluvial plain and swamp facies.

The brown coals of the Mamyt formation are petrographically complex and consist of alternating thin bands of plant matter in different stages of coalification. They are thin bedded, flaky, sooty and earthy. Petrographically they are either durain-clarain or clarain-durain coals, depending on the predominance of one or the other of these components.

The laminated variety of coal is composed of shreds of lignin-cellulose tissue cemented with weakly jellified brownish-yellow colloidal humic material.

The lignite variety retains the structure of the cellulose in different stages of jellification. This material constitutes 2 to 5% of the bulk composition of the coal.

The earthy and sooty coals are composed of attritus in uniformly fine and mixed particles. The microscope shows that the intensely black, opaque attritus constitutes from 35 to 40% of the total mass of the coal, while the dense component strongly impregnated with humic matter amounts to only 20-25%. It consists of carbonized plant remains and forms dense brittle bright or dull layers and lenses from 0.5 to 2 millimeters in thickness. In thin sections, this material is opaque or translucent and is seen to be composed of fusain, durain or durain-clarain.

The parent material of the coals of the Mamyt formation was humic and only rarely does the microscope reveal a slight admixture of sapropelic material.

After a study of the coals of the Orsk basin, E.I. Tarakanova divided them according to the ratio of the amorphous jelly to fusain into two genetic types: 1) coals with dominant amorphous jelly and 2) coals with dominant fusain. Each type was subdivided according to the degree of brightness into semi-bright, semi-dull and dull.

The composition of the coals (in % of the combustible fraction) is as follows: 61.54 to 78.20% carbon, 71.0% on the average, and 3.2 to 5.79% hydrogen, or 4.29% on the average. The coals are typically brown humic. They were formed in a partially reducing environment of fresh and brackish water basins.

The Mamyt formation contains abundant plant fossils which establish its age. I determined the composition of its spore-pollen assemblage composed of 40 to 45% spores and 55 to 60% pollen.

The most abundant spores are: Dicksonia, 1-2%; Coniopteris, 20-40%; Gleichenia, 1%; Matonia, 2-10%; Cladophlebis, 1-2%; Cheropleuria, 0.5-1%; Acrostichum, 1%; Hausmannia, 1-2%; Hymenophyllum, 1-2%; Cyathea, 1-5%; Osmunda, 5-20%; Lygodium, 1%; Lycopodium, 2-5%; Selaginella, 2-5%; Phlebopteris, occasional grains; Equisetum, 5-10%; Leiotriletes, 5-10%; Stenozonotriletes, occasional grains; Eurizonotriletes, occasional grains; Marattiaceae, 3-5%; Chomotriletes, occasional grains; and Polypodiaceae, 1-5%. The content of the Lower Jurassic forms such as Bernouillia and the spores of the Danae, Danaeopsis, Klukia and other types is negligible and amounts to tenths of one percent. The pollen of gymnosperms accounts for 10-15% and of conifers to 30-45%. The gymnosperms are represented by Ginkgoales, Cycadales and Bennettitales, and the conifers by Podozamites, Caytonia, Podocarpus, Piceae, Pinus haploxylon, P. subconcina Naum., Aliferina variabilis Mal and others. The spores of Coniopteris predominate in the assemblage but less so than in the Khaybulino formation. The pollen of cycads and conifers is much more abundant than in the older formation. On the whole, the dominant forms in the spore-pollen complex are Middle Jurassic, Bajocian-Bathonian. The complex correlates with the Bajocian-Bathonian complex of the Uralo-Caspian defined by E.L. Kopytova.

In 1954, Genkina collected and identified a rich flora from the Mamyt formation. This flora is not only richer in species than the flora of the Khaybulino formation but is different in composition and contains plant associations indicative of a sharp climatic change. The Mamyt flora contains no Pagiophilum peregrinum Lindl. et Hutt., Hausmannia buchii Andr. and other forms occurring, although not abundantly, in the Khaybulino formation.

Besides the widespread transitional forms of ferns, conifers, ginkgos and bennettites, the lowermost coal ved (IV) is very rich in cycads: Nilssonia orientalis Heer, N. Vittaeformis Pryn., N. mediana (Lesk.) Fox-Str., N. compta Phill., N. gracilina Heer, N. schmidtii Heer, N. cimpersaica Gen., and others which are not found in the Khaybulino formation.

Such cycads as Nilssonia mediana Lesk., N. acuminata Schenk, Ctenes, Ptilophyllum and others are occasionally found in the middle and upper parts of the Khaybulino formation. These plants are evidently ancestral to the cycads, which reached their highest development during the deposition of the Mamyt sediments in response to the changing climate.

Bed IV is a key bed used in tracing the boundary between the Khaybulino and Mamyt formations, although locally the lithological boundary lies a little below it. Near the sides of the basin the boundary is sharp and is drawn on the lithological basis, but with increasing distance from the margins of the basin it becomes less pronounced and is drawn with the aid of bed IV, a little below its base. Where bed IV is absent the boundary is drawn by its facies analogue, a cycad-bearing layer of clay and silt. In the deepest parts of the basin the boundary between the formations is so indefinite that it can be drawn only by logging.

Visually the Mamyt formation is distinguished from the Khaybulino formation by the proportion of rock types and by a slightly different mineralogical composition. The Mamyt formation is essentially carbonate-free, and siderite is very rare in it, while in the Khaybulino formation sand and silt predominate over clay, siderite layers are quite common throughout its extent and the silty clays are often slightly calcareous. Thus, each of the two formations has its own persistent lithofacies as well as paleobotanical characteristics.

The flora of the Mamyt formation, determined by Genkina, has the following characteristic composition: Williamsonia pacifica Krysht., W. orientalis Krysht., Coniopteris hymenophylloides (Brongn.) Sew., C. furssenkoi Pryn., C. angustiloba Heer, Coniopteris zindanensis Brick., Cladophlebis denticulata (Brongn.) Font., Cl. whitbiensis Brongn., Cl. mamitiensis Gen., Cl. lobifolia Krysht., Cl. suluctensis Krysht., Raphaelia diamensis Sew., Equisetites ferganensis Sew., E. hallei Trom., T. beanii Bunb., Pterophyllum (Anomozamites) lindleanus Shimp., Ptilophyllum cutchensis Morr., Nilssonia orientalis Heer, N. vittaeformis Pryn., N. mediana (Lesk) Fox-Str., N. compta Phill., N. gracilina Heer, N. schmidtii Heer, N. denticulata Heer, N. acuminata Presl., Ctenes Jokoyamaie Krysht., Ginkgo lepida Heer, G. sibirica Heer, G. digitala Brongn., G. concinna Heer, Baiera pulchella Heer, Phoenicopsis angustifolia Heer, Ph. speciosa Heer, Czekanowskia rigida Heer, Pityophyllum hordenskioldii Heer, Brachyphyllum (Stenb.) Sew., Brachyphyllum obesum Heer, Pagiopryllum williamsonia Lindl. et Hutt., Pagiophyllum setosum Sew., Drepanolepis angustior Nath., Schizolepis braunii Schenk. This assemblage dates the formation as Bajocian-Bathonian and correlates it with the Zholdybayev formation (J_2^{bj-bt}) of the Caspian depression in the region of the South Emba oil fields. Moreover, the flora and the spore and pollen spectrum of the Mamyt formation correlate it very well with the Duzbay formation of the Ubogan basin. The thickness of the Mamyt formation ranges from 42 to 170 meters. The average thickness is 110 meters.

The Ziren-Agach formation is widespread in the northern part of the interior depression of the Orsk Urals in the Baymak, Priirendyk, Akkerman and Orsk basins. In the Baymak and Priirendyk basins it lies with an erosional unconformity on the Khaybulino formation, and in the southern part of the Akkerman basin and the northern part of the Orsk basin it is conformable on the Mamyt formation. The northern areas of the Priirendyk and Baymak basins contain mainly fanglomerate sediments composed of gravels and coarse sands passing to the south into fine-grained sands, silts and clays. It was pointed out by Yanshin that the deposition of the Ziren-Agach formation was preceded by renewed uplift of the anticlines, which increased the rate of erosion and caused the deposition of coarse-grained clastics.

The extent and boundaries of the Ziren-Agach formation in the northern part of the Orsk interior basin remain as defined by Yanshin. In the Akkerman and Orsk basins the formation is represented by vari-colored sands and clays. It is distinguished mainly on lithological grounds, and its separation is confirmed by spore-pollen analysis. Plant remains are very rare in it and are poorly preserved. The spore-pollen assemblage of the Ziren-Agach formation, determined by E.N. Silina, is typical of the upper Middle Jurassic and contains: Klukia sp., Psophosphaera sp., Cibotium sp., Selaginella, Cycadaceae, Polypodiaceae, Caytoniales, Podozamites, Tetraporina, Pinacea, Psophosphaerae, Trachitriletes sp., Stenozonotriletes, Leiotriletes, Leptochylus sp., Lygodium, Matonia, Schizaea, Ophyoglossaceae.

Besides the typical Middle Jurassic forms, younger forms have been found in the formation, including Brachyphyllum sp., Tetraporina and Schizaea. Tetraporina is one of the primitive angiosperms of the transitional zone and the upper Middle Jurassic strata. This assemblage is younger than that in the Khaybulino and Mamyt formations and dates the Ziren-Agach formation as Middle Jurassic.

The Ziren-Agach formation in the Orsk Urals lies at the top of the Middle Jurassic section, and in the Akkerman basin near the Babak triangulation tower it is overlain by Cretaceous and Tertiary sediments.

REFERENCES

1. Belousov, V.V., GEOTEKTONIKA [GEOTECTONICS]: Geolizdat, 1954.

2. Malyutina, Z.A., STRATIGRAFIYA I LITOLOGIYA UGLENOSNOY TOLSHCHI VOSTOCHNO-URAL'SKOGO BUROUGOL'-NOGO MESTOROZHDENIAY [STRATIGRAPHY AND LITHOLOGY OF THE COAL-BEARING STRATA OF THE EAST URALIAN LIGNITE DEPOSIT]: Tr. Labor. geol. yglya Akademiya Nauk SSSR, vyp. 6, 1956.

3. Razumovskiy, N.K., A.V. Khabakov and B.V. Nalivkin, GEOLOGICHESKOYE STROYENIYE ORSKO-KHALILOVSKOGO RAYONA [GEOLOGICAL STRUCTURE OF THE ORSK-KHALILOVSK REGION]: Geoltekhizdat, 1941.

4. Yanshin, A.L. and P.L. Bezrulov, GEOLOGICHESKAYA S"YEMKA GLAVNOGO PYATNA MESOZOISKIKH OTLOZHENIY YUZHNOGO URALA [GEOLOGICAL MAPPING OF THE MAIN EXPOSURE OF THE MESOZOIC DEPOSITS IN THE SOUTHERN URALS]: Tr. N.-i. in-ta geol. i mineralog., vyp. 6, 1934.

5. __________, YURSKIYE OTLOZHENIYA I MESTOROZHDENIYA BOKSITOV NA YUZHNOM URALE [JURASSIC DEPOSITS AND DEPOSITS OF BAUXITE IN THE SOUTHERN URALS]: Tr. N.-i, in-ta geol. i mineralog., vyp. 7, 1934.

Chelyabinsk Geological
and Prospecting Organization

Received June 21, 1958

THE ALKUN ZONE AND ITS STRATIGRAPHIC SIGNIFICANCE[1]

by

R. G. Dmitriyeva, V. D. Somov and A. K. Bogdanovich

The finding of new productive gas and petroleum deposits in the sediments of the Maikop series of the Caucasus demands particularly careful investigation of its stratigraphy and the development of a unified system of subdivision to replace the numerous local systems existing at present [1, 2, 4-7].

Of considerable interest in constructing such a unified scheme of subdivision is the so-called Alkun zone, or, as it is frequently called, the "marl-dolomite complex" [4]. This zone, lying in the middle part of the Maikop series, is stratigraphically persistent and traceable over an extensive area of Eastern Ciscaucasia.

It should be noted that the published data on the Alkun zone are very scattered and incomplete. This is especially true of the carbonate facies of the zone, whose structural characteristics and petrography are very little known. The paleontology of these sediments is also very incompletely known and their distribution and boundaries in the investigated region have not been agreed upon.

Having at our disposal extensive observations on the stratigraphic position of the Alkun zone and on its lithology, petrography and paleontology, we decided to publish our data and thus fill the gap in the knowledge of these sediments.

Our work is based on field investigations made at different times (from 1950 to 1957) in Ciscaucasia between the Sulak River in the east and the Belaya River in the west. The lithological-paleontological laboratory work was also used in preparing this paper. The fossil floras were determined by E.N. Kara-Murza.

In order to give a clear idea of the character of the Alkun zone in each of the investigated areas and of its relation to the underlying and overlying beds, brief descriptions of the sections based on our observations are given in the first part of the paper. The second part contains a general account of the zone and a discussion of its stratigraphic significance.

I

We shall begin the description of the Alkun sediments with the section on the Assa River, which was used by K.A. Prokopov [4] as the type section of the Alkun zone. This section is very well exposed on Alkunka Creek, the left tributary of the Assa River, near the northern end of the village of Nizhniy Alkun, and is described below.

1. The arenaceous-argillaceous sediments of the Mutsidakal formation are overlain by dark-gray and gray laminated, noncalcareous silty clays containing infrequent layers of gray, well cemented siltstone. Elongated lenses of dark-gray argillaceous limestone with septarian structure and diameters of 0.3 to 0.5 meter are occasionally found among the clays. The clays contain sparse fish fossils (mainly scales) and occasional very small and usually mineralized shells of Globigerina sp. and Gümbelina sp. The thickness of the clays is about 37.0 meters.

2. Unit 1 is overlain by the same clays with thin layers of gray calcareous siltstone increasing in number and thickness towards the middle of the section. There are septarian concretions of dark-gray marlstone and argillaceous limestone. The concretions, 0.5 to 1.5 meters in diameter, increase in number in the upper layers and form three or four indistinct rows. Fish scales occur sparingly. The thickness of the unit is not less than 30.0 to 35.0 meters.

3. Higher in the section, along the road between the villages of Nizhniy Alkun and Muzhichi, lies a bed of very large loaf-like lenses of dark-gray very dense dolomitized

[1] Alkunskiy gorizont i yego stratigraficheskoye znacheniye.

argillaceous limestone up to 5.0 meters in length. The unit is 0.3 to 0.4 meter thick.

4. Unit 3 is overlain by dark-gray silty laminated clay, ferruginous, noncalcareous with infrequent thin (0.01 to 0.02 meter) layers of light-gray siltstone. In the upper part the clay beds contain a little carbonate and become platy. The fossils found in the clays include fish scales and a few shells of very small foraminifera: Uvigerinella aff. californica, Cushm., U. sp., Angulogerina sp., Bolivina ex gr. plicatella Cushm., B. sp., Cibicides amphysyliensis (Andreae), Nonion martkobi Bogd., N. sp., Discorbis sp. and Globigerina sp.

Sometimes associated with these foraminifera are shells of large strongly mineralized globigerina redeposited from the foraminiferal deposits. At the top of the clay beds, in the platy clays, there are remains of brown algae, of the genus Cystoseira: Cystoseira aff. partscrii Pila., C. filiformis Sternb. and C. sp. Thickness, 19.5 meters.

5. Above unit 4 lies dark-gray platy slightly calcareous silty clay with thin layers of calcareous argillaceous siltstone. The base and the top of the unit each contains a layer of dark-gray argillaceous platy dolomitic limestone. The thickness of the layers is 0.10 and 0.22 meter, respectively. The clay contains foraminifera and Cystoseira. Its thickness is 3.5 to 3.7 meters.

6. The clays higher in the section contain rather numerous thin layers of siltstone and belong to the Assa zone. No carbonate concretions have been found in the lower part of the zone.

In this section beds 3 - 5 belong to the Alkun zone, and the upper layer, composed of platy carbonate and clay layers and containing algae, may be separated as the Cystoseira argillaceous dolomite bed. The thickness of the Alkun zone on the Assa River is 23 meters. In our opinion the underlying beds 1 and 2 belong to the Argun zone.

To the east of the section just described, we investigated the Alkun sediments along the Chanty-Argun and Sulak rivers.

The sequence of units in the section on the left bank of the Chanty-Argun River above the village of Shishki is as follows:

1. The Mutsidakal arenaceous-argillaceous sediments are overlain by dark-gray noncalcareous clay containing infrequent thin siltstone layers. Ellipsoidal septarian concretions of brown marlstone appear 30 to 35 meters above the base. They are up to 0.6 to 1.0 meter in length and sometimes form rows. The clay contains a few small fish scales. Thickness — 110 to 115 meters.

2. Above unit 1 lies dark-gray, slightly silty, noncalcareous clay with relatively small separate lenses of marlstone and a 0.3 meter layer of dark-gray marlstone at the base. The clay contains a few fish scales. Thickness — 2.8 to 3.0 meters.

3. This unit contains the same clay with small marlstone lenses and a layer of elongated lenses of dark-gray marlstone at the base. Thickness — 9.3 meters.

4. Overlying unit 3 is dark-gray, slightly silty, noncalcareous clay with thin partings of dark siltstone and infrequent small flat lenses of marlstone. At the base there are large loaf-like concretions of dark-gray, locally platy argillaceous limestone 3.0 to 4.0 meters long and 0.6 meter thick. At the top there is a layer of gray platy dolomitized limestone 0.4 meter thick. A few fish scales occur in the clay, and the platy marlstone and dolomitized limestones contain rather abundant impressions of Cystoseira sp. and a few fish scales. Thickness — 12 to 13 meters.

5. Unit 4 is followed by dark-gray, laminated, micaceous silty clay with rather numerous thin partings and occasional lenses of gray siltstone. At the very base, directly on the platy dolomitized limestone of unit 4, there lies a small lens of similar limestone 0.7 meter in diameter and 0.5 meter in thickness. The exposed thickness of the unit is 30 to 40 meters. Above this unit the sediments are concealed for a considerable interval.

Unit 1 of this section corresponds to the Argun zones first separated here by N.S. Zolotnitskiy (1938), units 2 - 4 we refer to the Alkun zone, and unit 5 to the Assa zone. Thus the sediments of the Alkun zone on the Chanta-Argun River are up to 25 meters thick and contain four layers of marlstone and dolomitized limestone. The upper two layers (unit 4) are platy, contain algae and may be correlated with the Cystoseira argillaceous dolomite bed separated by us on the Assa River.

In the region of the Sulak River the Alkun sediments were studied only on the left bank along Riki-Kol gully, which opens into the Sulak River a little above the abandoned village of Zuramakent. Here, on the right bank of the gully almost at the top of the spur, lie the Mutsikdal sediments composed of dense laminated clay with layers of cross-bedded siltstone. Down the gully and stratigraphically higher are:

1. Clays, gray, dense, laminated and noncalcareous, with occasional layers of cross-

bedded siltstones and a few lenses of siderite. The clays contain a few fish fossils. Thickness about 30 meters.

2. The same clays with rather numerous septarian marlstone and argillaceous limestone. The concretions are in more or less regular rows (up to six rows) and are 1.0 to 1.2 meters in diameter. The clay also contains very thin and sparse partings of siltstone. The thickness of the unit is 8 meters.

3. The same clays, but strongly enriched in jarosite, which gives them a lighter yellowish color. Septarian concretions are absent, but layers of gray siltstones are common and range from very thin to 5 to 10 centimeters in thickness. Moreover, the upper part of the unit contains very few small lenses of dark-gray dense siderite. The only fossils are occasional fish scales. The thickness is about 100 meters.

4. Gray noncalcareous laminated clays with numerous patches of jarosite and three layers of carbonate rocks. The lowermost of these is a 0.4 meter layer of very large closely spaced and even coalescing lenses of light-gray argillaceous limestone. The middle layer is composed of dark-gray dolomitized limestone locally swelling into lens-like forms and possessing well developed platy structure; its thickness is 0.25 to 0.30 meter. The upper layer consists of concretions of the same dolomitized limestone and is up to 0.25 meter in thickness. A few fish scales occur in the clay. The middle layer of dolomitized limestone contains numerous fish fossils (scales, bone fragments) and fragments of algae: Cystoseira aff. partschii Pilar. and C. sp. Total thickness — 14 meters.

The three carbonate layers of unit 4 are easily traced at the base of the right bank of Riki-Kol gully near its mouth. Higher up the gully these layers outcrop on its floor and still higher on its left bank. Here, lying directly on unit 4, are:

5. Dark-gray laminated noncalcareous clays with abundant patches of jarosite and very infrequent siltstone partings. In the upper part of the unit there are very large (up to 1 to 2 meters in diameter) Septarian concretions of marlstone and dolomitized limestone. The concretions lie in 3 to 4 rows. Thickness — 55 to 60 meters.

This section corresponds to a considerable part of the Riki zone described by N.S. Shatskiy in 1929 and is subdivided by us as follows: units 1 to 3, we refer to the Argun zone; unit 4, to the Alkun zone; and unit 5, to the Assa zone.

In the Sulak River section the Alkun zone is represented by about 14 meters of clay containing three layers of dolomite and limestone. The middle layer has well developed platy structure, contains numerous remains of algae and correlates with the above described Cystoseira bed. It should be added that these three carbonate layers in Riki-Kol gully were first described by K.A. Prokopov and A.A. Khutsiyev in 1933 and correctly regarded by them as analogues of the Alkun zone on the Assa River. The same authors state that the Alkun limestone-dolomite sequence of Riki-Kol gully is underlain by the arenaceous-argillaceous sediments of the Mutsidakal formation. As can be seen from the above description of the section, its upper part (units 1 - 3) contains in some places large septarian concretions which indicate that the sediments are analogues of the Arguz zone. This zone is underlain by the sand-clay sequence referred by Shatskiy [7] to the Mutsidakal zone.

To the west of the Assa River we investigated the Maikop sections on the Fiagdon, Urukh, Kuban' and Belaya Rivers.

On the right bank of the Fiagdon River, 3 kilometers above the village of Dzaurikau, the Mutsidakal sands and clays are followed by an interruption in the exposure and then by:

1. Dark-gray, sometimes greenish laminated clays essentially noncalcareous, with thin partings of fine-grained gray sand and siltstone. The clay contains occasional very small Globigerina sp., Ammodiscus aff. tenuiculus Subb., Haplophragmoides sp. and fish fossils. There are many interruptions in the exposure of this unit. Its thickness is 90 to 100 meters.

2. Lithologically similar clay containing a large ellipsoidal concretion of argillaceous limestone at the base. The concretion is over 1.5 meters in length and about 0.4 meter in thickness.

3. The same clay with a row of concretions of dark-gray dolomitized argillaceous limestone (up to 0.5 m in length) at the base. Thickness about 2 meters.

4. The same clays with a layer of dark-gray platy dolomitic limestone up to 0.4 meter in thickness at the base. The individual lenses are often 2.0 meters in length and contain imprints of Cystoseira sp. The clay contains sparse Ammodiscus sp. and fish scales. Thickness 12.0 — 12.5 meters.

5. Unit 4 is followed by a layer of yellowish-gray dolomitic limestone in loaf-like lenses up to 2.0 meters in length. Thickness 0.2 meters.

6. Higher, on the right bank of the river, extending nearly to the bridge, there is a frequently interrupted outcrop of dark-gray laminated noncalcareous, usually silty clays with occasional partings of gray siltstone. Septarian marlstone concretions up to 0.3 meter in length and 0.12 meter in thickness occur sparingly 35 to 40 meters above the base of the unit. The clays contain a few fish scales and occasionally very small shells of Globigerina sp. and small monaxons of siliceous sponges. The exposed thickness of the unit does not exceed 110 to 114 meters.

In this section, units 2 to 5 must be referred to the Alkun zone, unit 1 represents the upper and greater part of the Argun zone, and unit 6 the Assa zone. Thus, the Alkun zone on the Fiagdon River contains three layers of limestone and dolomite, of which the middle one (in unit 4) has platy structure, contains imprints of algae and corresponds to our Cystoseira bed. The thickness of the Alkun zone is up to 35 to 36 meters.

On the right bank of the Urukh River near the village of Akhsarisar the arenaceous-argillaceous sediments of the lower Maikop are followed after a considerably disconformity by the following units:

1. Dark-gray, sometimes greenish laminated noncalcareous sandy and silty clay with infrequent partings of yellowish-gray siltstone. The clay contains a few fish remains (mainly scales). Thickness 15 to 16 meters.

2. The same clays with thin lenses of gray noncalcareous siltstone and rather numerous septarian concretions of gray marlstone and argillaceous limestone lying in three fairly regular rows. The diameter of the concretions ranges from 0.3 to 1.0 meter. A few fish scales. Thickness 8 to 9 meters.

3. Loaf-like lenses of dark-gray dolomitized marlstone up to 2 meters in length. Thickness about 0.4 meter.

4. Dark-gray thin-bedded clays silty and sandy, mainly noncalcareous locally calcareous, with two rows of flat argillaceous limestone concretions. The length of the concretions is up to 1.0 meter; their thickness 0.15 to 0.20 meter. The clays contain fish scales, and the calcareous clays, relatively few Bolivina ex. plicatella Cushm., Uvigerinella sp. (young Uvigerinella ex. gr. californica Cushm.?), Nonion martkobi Bogd., Globigerina sp. and Orbulina (?) micra Subb. Thickness about 15 meters.

5. Same clays with a layer of large lenses (up to 1.0 to 1.5 meter in diameter) of gray argillaceous limestones at the base. The clays contain a few fish fossils and occasional very small foraminifera: Bolivina ex. gr. plicatella Cushm., B. sp., Uvigerinella sp., Eponides sp., Orbulina (?) micra Subb. and Globigerina sp. Besides this microfauna, the six-rayed spicules of siliceous sponges are occasionally found. Thickness about 1 meter.

6. A layer of gray platy dolomite with a few fish scales. Thickness 0.6 meter.

A recent slide made it impossible to examine the unit overlying unit 6. According to V.N. Golozubov, who described the Maikop series on the Urukh River in 1949, the platy dolomite is overlain directly by:

7. Dark-gray thin bedded sandy and silty noncalcareous clay containing thin (up to 0.01 meter) lenses of siltstone and large septarian marlstone concretions with diameters from 1.0 to 1.5 meters. The concretions apparently form two poorly defined rows. Thickness about 13 meters.

Unit 7 is overlain by lithologically similar clay locally containing large septarian concretions and belonging to the Assa zone.

Units 1 - 3 of the above section we refer to the Argun zone; units 3 - 6, and tentatively unit 7, to the Alkun zone. The latter contains 5 to 7 layers of limestone and dolomite, and the platy layer very likely corresponds to the Cystoseira bed of the preceding sections. The thickness of the Alkun zone in this section is apparently 30 meters.

On the Kuban' River the part of the Maikop series under discussion is exposed on the right bank of the river near Cherkassk, between a small bridge leading to the city park on an island and the northern city limits. Here, about 40 to 50 meters above the top of the Khadum zone, lie the following rocks, in ascending order:

1. Dark-gray brownish thinly laminated noncalcareous clay containing infrequent layers and small lenses of brownish-gray marlstone. In the upper part of the unit the number of marlstone inclusions increases and they take the form of elongated rounded, mostly septarian concretions. The concretions form rows spaced 10 to 15 meters apart. They are usually small, but sometimes reach 1 to 1.5 meters in diameter and 0.5 meter in thickness. The clay contains fish fossils. The thickness of the unit is 100 to 110 meters.

2. The same clays with two rows of loaf-like lenses of gray argillaceous limestone. The lenses almost coalesce and are 3.0 to 4.0 meters long and 0.5 meter thick. Thickness 4 meters.

3. The same clays but with more numerous

lenses of dolomitized marlstone and limestone lying in three rows. Thickness 8.0 to 8.5 meters.

4. Dark-gray layered noncalcareous clay. Slightly calcareous clay occurs in the upper part of the unit and contains very scarce randomly distributed marlstone and limestone concretions. At the top there are enormous brownish-gray loaf-like concretions of dolomitized marlstone with an exposed length of over 2.0 meters and thickness of 0.5 to 0.5 meter. The calcareous clay contains occasional Bolivina ex gr. plicatella Cushm., Discorbis sp., Ammodiscus tenuiculus Subb and bean-like spicules of siliceous sponges. Thickness 9 to 10 meters.

5. Clay similar to the preceding but more calcareous. At the base of the unit half a meter above the level of the loaf-like concretions of unit 4 there is a layer of enormous lenses of platy dolomitized dark marlstone lying close together. The length of the lense is over 2 meters and the thickness up to 0.25 meter. At the top of the unit lies a layer of marlstone lenses identical in composition but lying far apart. In both layers of marlstone lenses and in the clay between them, fragments of Cystoseira sp. were found. The clay also contains fish scales, rather abundant Bolivina ex gr. plicatella Cushm., Uvigerinella sp., occasional Ammodiscus tenuiculus Subb. and spicules of siliceous sponges. Thickness 4 meters.

6. The same clay, both calcareous and noncalcareous, with relatively thin layers and elongated lenses of dark-gray platy dolomitized marlstone. The largest number of marlstone lenses is in the middle part of the unit, where they can be traced in three to four rows spaced 2 to 3 meters apart. The clay contains fish scales and occasional spicules of siliceous sponges. Thickness 16 to 20 meters.

7. A layer of enormous loaf-like concretions of dark-gray dolomitized marlstone and dolomitic limestone similar in appearance to the carbonat rocks of units 2 and 5. The length of concretions is about 2.0 meters. The thickness of the unit is 0.5 meter.

8. Dark-gray, noncalcareous clay with two rows of concretions of gray dolomitic limestone in the lower part of the unit. The concretions are septarian and reach 0.7 meter in diameter. The clays yielded a few fish fossils. The exposed thickness of the unit is about 5 to 6 meters. The beds above it are concealed for a considerable distance.

This section of the Maikop series on the Kuban' River was described by Prokopov in 1937 under the name of Batalpashinsk zone. The upper part of the section, i.e. unit 8, apparently corresponds to the septarian zone of the same author. A comparison of these sediments with the other sections of the Maikop series enables us to refer units 2 to 7 to the Alkun zone, and the upper part of unit 1, containing rather numerous septarian concretions, to the Argun zone. The lower clay of unit 1, with very sparse carbonate inclusions, must correspond stratigraphically (down to its contact with the Khadum zone) to the sandy-clayey Miatlin-Mutsidakal sequence of Eastern Ciscaucasia.

Thus, the Alkun zone is represented on the Kuban' River by clay beds containing 10 to 12 layers of carbonate rocks (marlstone, dolomite and limestone) and is up to 42.0 to 45.0 meters in thickness. The two rows of lenses of platy dolomitized marlstone with algae (unit 5) in its middle part undoubtedly correspond to the clay-dolomite Cystiseira bed. It is very probable that it is precisely these beds and the underlying sediments of unit 4 that were regarded by N.S. Zolotnitskiy as the analogues of the Alkun sediments.

The last of the sections examined by us is on the right bank of the Belaya River near the mouth of the Gyunt' gully about 0.5 kilometer below Abadzekhskaya station. Here, above the sediments of the so-called Abadzekh formation defined by S.T. Korotkov (1940) and above a considerable interval without exposures, lies the following sequence of beds in ascending order:

1. Dark-gray laminated noncalcareous clay with two rows of argillaceous limestone lenses lying 7 to 10 meters apart and reaching 0.4 to 0.7 meter in diameter and 0.10 to 0.15 meter in thickness. The clay contains a few fish scales. The thickness of the unit is about 6 to 8 meters.

2. No outcrops for about 4 to 5 meters.

3. Light-gray laminated clays, locally platy and calcareous to varying degrees. At the base of the unit there is a row of strongly flattened limestone concretions up to 0.3 to 0.5 meter in diameter and up to 0.1 meter in thickness. In the middle part of the unit lies a second row of argillaceous limestone inclusions in the form of large (up to 0.8 meter) pancake-like lenses with platy structure. The clay locally contains imprints of algae very similar to Cystoseria sp., occasional very small petropods, possibly Spiralis, and rather abundant foraminifera: Bolivina ex gr. plicatella Cushm., B. ex gr. floridana Cushm., Virgulinella sp., Uvigerinella aff. californica Cushm., Cibicides amphisyliensis (Andreae), Discorbis sp., Ammodiscus tenuiculus Subb. and some others. The thickness of the unit is about 10 to 11 meters.

The sediments above unit 3 are concealed for a considerable distance and then follow the sands and clays of Korotkov's so-called Yoskovgory formation.

The investigated part of the section (units 1 - 3) probably corresponds to the upper part of Korotkov's Abadzekh formation or to his "beds with septarian concretions" which he correlates with the Alkun zone. The exposed portion of the zone on the Belaya River is composed of clays with exposed thickness of 20 to 30 meters. Of the four carbonate layers, the upper layer and the clays with imprints of algae enclosing it evidently corresponds to the *Cystoseira* argillaceous-dolomite bed described by us from the eastern sections.

II

An analysis of the sections of the Alkun zone shows that it is composed mainly of clays with included carbonate rocks varying in form and structure. The clays are dark-gray, sometimes greenish or brownish, and include noncalcareous and silty varieties. In some sections the clays are calcareous and almost free of silt. The clays are usually dense and unstratified, but have flaky cleavage and platy structure. The platy clays break up into large plates of varying thickness.

Occasionally stratified clays are found, the finer stratification being due to alternation of layers of dark-gray clay and gray silt and the coarser, to the presence of widely spaced layers of siltstone. The main material of the clays is hydromica occurring in fine scales [3].

The clays of the Alkun zone contain sparse fish fossils (mainly small scales) and locally impoverished faunas of undersized foraminifera: *Uvigerinella* aff. *californica* Cushm., *U.* sp., *Bolivina* ex gr. *plicatella* Cushm., *B.* ex gr. *floridana* Cushm., *Angulogerina* sp., *Nonion* aff. *martcobi* Bogd., *N.* sp., *Cibicides amphysiliensis* (Andreae) *Discorbis* sp. and some others. This assemblage is usually found in slightly calcareous clays and is known from sections on the Assa, Urukh, Kuban' and Belaya rivers. It is important to note that the platy variety of clay from the Assa River section contains rather abundant remains of brown algae: *Cystoseira filiformis* tsernb., *C.* aff. *partschii* Pilar and *C.* sp.

The carbonate rocks are a characteristic feature of the Alkun zone and are usually marlstones, argillaceous limestones and argillaceous dolomitic limestones. They occur in small concretions or in very large loaf-like lenses (over 2 m in length) lying in contact with one another or apart and in continuous layers.

The small concretions and loaf-like lenses often have septarian structure and are composed of marlstone and argillaceous limestone frequently partly dolomitized. The carbonate content in the marlstones does not exceed 68-74%, but in the limestones it is 80-85%. No regularity has been observed in the distribution of the carbonate rocks in the zone. The small concretions occur at random throughout the clays, but sometimes form rows wedging out along the strike. The large loaf-like lenses usually lie in rows which are quite persistent in some regions but are not restricted to any particular level within the

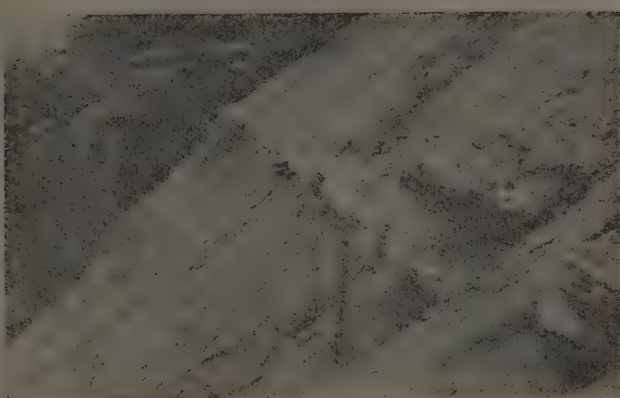

FIGURE 1. Platy dolomitized limestone with *Cystoseira*. On the Chanta-Argun River.

zone. The number of such rows of marlstone or limestone lenses varies from two (Sulak River) to three and four (Urikh and Kuban' rivers).

The continuous carbonate layers in almost all sections are composed of dolomitic limestone and only infrequently (for example on the Chanty-Argun River) of dolomitized limestone containing from 76 to 85% of soluble matter. A very characteristic feature of these rocks is their platy structure and the constancy of their paleontological characteristics. In most sections these rocks contain Cystoseira aff. partschii Pilar and Cystoseira (Figs. 1 and 2). Very often, one or two carbonate layers lie in the middle or upper part of the Alkun zone. In some sections (on the Fiagdon, Kuban' and Belaya rivers) these layers are not continuous but consist of separate large lenses all with platy structure and the same assemblage of brown algae.

A brief account of the microscopic characteristics of the carbonate rocks is given below.

The marlstones and argillaceous limestones of the Alkun zone consist mainly of cryptocrystalline calcite (0.005 - 0.008 mm) with a greater or less amount of clay. Sometimes the cryptocrystalline calcitic groundmass contains grains of siderite and dolomite (0.05 - 0.06 mm). The detrital material is usually absent.

The groundmass of the dolomitic limestones is composed mainly of small rhombohedra of dolomite ranging from 0.03 - 0.05 to 0.01 - 0.02 millimeters in size, lying close together and forming a mosaic. The interstitial material is cryptocrystalline calcite with grains not exceeding 0.008 - 0.016 millimeters in diameter. It should be noted that the carbonate material of these dolomites usually forms alternating layers of cryptocrystalline calcite with argillaceous admixture and of fine-grained mosaic consisting almost entirely of dolomite rhombs. It is not improbable that the platy structure so characteristic of the dolomitic limestones is due to this alternation of calcite and dolomite layers.

It is noteworthy that the texture and composition of the carbonate rocks persists without any notable change over the entire investigated area. An exception to this are the platy carbonate inclusions (lenses) in the Belaya River section which are composed of slightly dolomitized argillaceous limestone with the soluble part amounting to 85 to 92%. The microscope shows that these rocks have a groundmass of cryptocrystalline calcite containing small, rather evenly distributed spots of gel-like argillaceous material.

These data show that the Alkuz zone possesses certain definite lithological and in part paleontological characteristics. In our opinion the most important of these is the presence of a persistent platy bed of argillaceous dolomite with Cystoseira. This platy dolomite (occurring in one or two layers) and the enclosing clay contain, in most of the sections, the characteristic imprints of algae of the genus

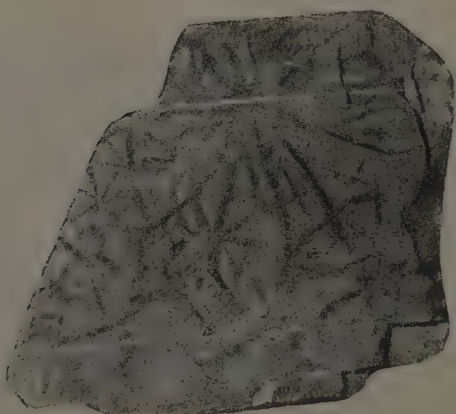

FIGURE 2. Dolomitized limestone with imprints of Cystoseira (Sulak River)

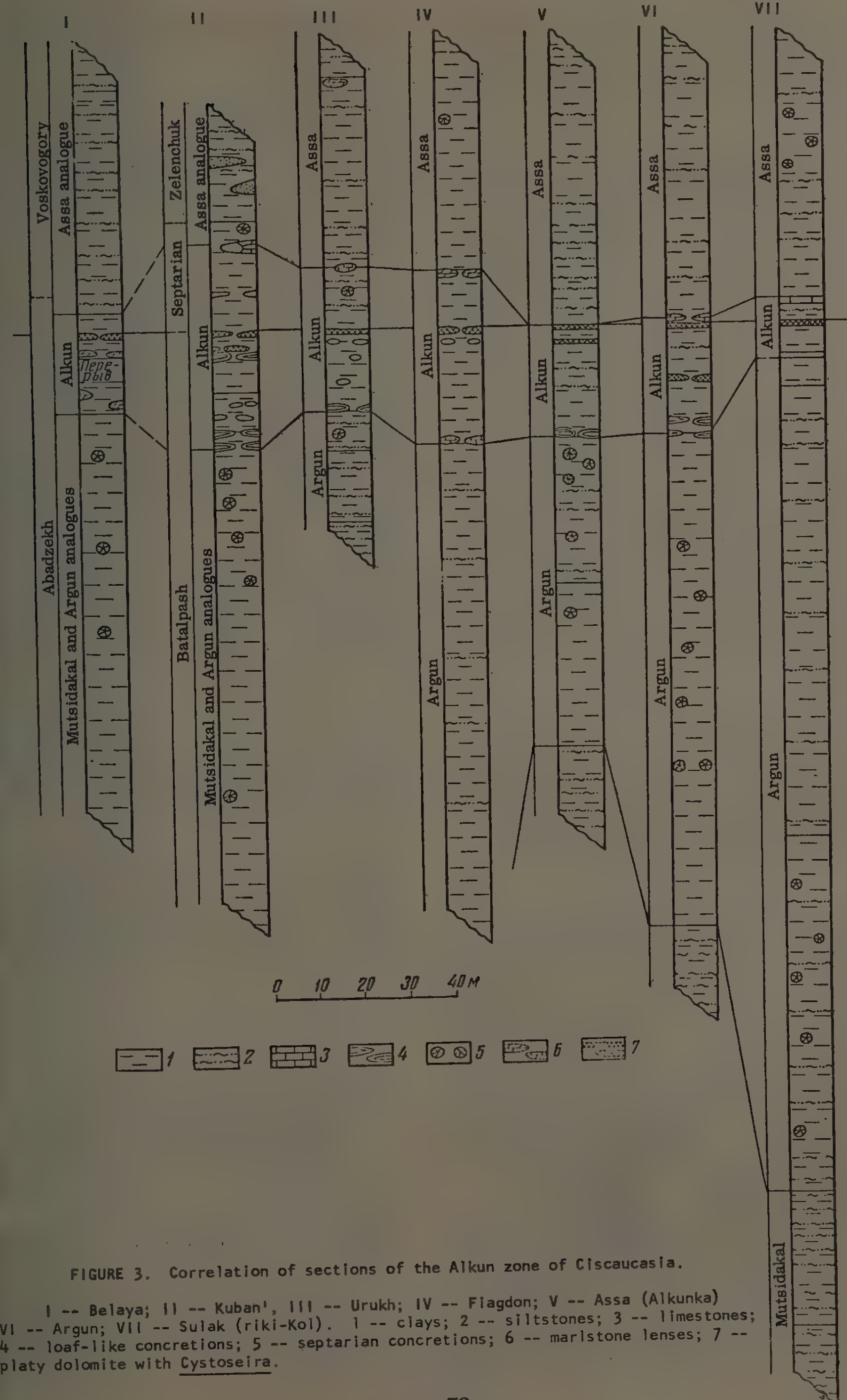

FIGURE 3. Correlation of sections of the Alkun zone of Ciscaucasia.

I -- Belaya; II -- Kuban', III -- Urukh; IV -- Fiagdon; V -- Assa (Alkunka) VI -- Argun; VII -- Sulak (riki-Kol). 1 -- clays; 2 -- siltstones; 3 -- limestones; 4 -- loaf-like concretions; 5 -- septarian concretions; 6 -- marlstone lenses; 7 -- platy dolomite with Cystoseira.

Cystoseira. Moreover, the clay of this bed (usually slightly calcareous) on the Assa and Belaya rivers contains most of the foraminifera listed above, including the typical Uvigerinalla aff. californica Cushm., Bolivina ex gr. floridana Cushm., and Nonion aff. martcobi Bogd.

The Cystoseira argillaceous dolomite usually lies in the middle part of the Alkun zone and, considerably less frequently, in its uppermost part (Fig. 3). It may be supposed, however, that the variation in the position of the dolomite is only a matter of appearance depending on the inexact marking of the top of the zone. Indeed, in the majority of sections (for example on the Sulak, Fiagdon and Kuban' rivers) above the argillaceous dolomite bed there are one or two rows of large loaf-like marlstone and argillaceous limestone lenses undoubtedly belonging to the Alkuz zone. In the sections on the Chanty-Argun and Assa rivers (along its tributary, the Alkunka River), the Cystoseira bed is not overlain by clearly defined layers of carbonate lenses and so appears to form the top of the zone. The possibility is not excluded, of course, that the apparent absence of these layers in the last two sections is a local feature due partly to poor exposure and that the Cystoseira bed occupies here the same middle position in the zone as in all other sections.

The position of the lower boundary of the Alkun zone is not very clear, and we are not completely convinced that it lies at the same stratigraphic level in all regions and especially in those distant from each other. The deviations of this boundary from the true position are not great, however, for the entire Alkun zone is relatively thin.

The lower boundary of the Alkun zone is usually marked at the first appearance in the section of rather large loaf-like marlstone or limestone lenses, frequently arranged in rows. These carbonate rocks are distinguished from the similar inclusions in the underlying Argun zone mainly by their structural characteristics and to some extent by their form. The carbonate inclusions of the Alkun zone are usually flattened lenses with poorly developed septarian structure or even without it. The analogous structures in the Argun zone are usually better rounded, sometimes nearly spherical concretions with well developed septarian structure.

It should be added that the same differences exist between the carbonate inclusions of the Alkun and Assa zones. Another distinctive characteristic of the Alkun carbonate rocks is the varying degree of their dolomitization. This characteristic is present to a very small extent in the analogous rocks of the Argun zone and is completely absent from those of the Assa zone.

In connection with the boundaries of the Alkun zone it should be noted that the thickness of the zone in the investigated area varies within rather narrow limits at any given exposure and increases regularly from east to west, from 14 meters on the Sulak River to 45 meters on the Kuban' River. The thickness of the Belaya River section could not be measured.

It may be concluded on the basis of the presented data that the Alkun zone with the typical platy argillaceous dolomite bed stands out quite clearly in the Maikop series over the entire area investigated by us and may serve as an excellent key zone in geologic mapping. It is important to emphasize that this zone, known until now only from the region of Chernyye Mountains, was traced by us on the basis of its lithological and paleontological characteristics in the Central and Western Ciscaucasia, where it had not been observed before. On the Kuban' River the typical carbonate rocks of the Alkun zone, including the platy Cystoseira dolomite, were traced by us in that part of the Maikop series which corresponds to the upper parts of the Batalpash zone of Prokopov's [5] local stratigraphic section and to a considerable part of his Septarian zone (Fig. 3).

In the Belaya River section (Western Ciscaucasia) the analogues of the platy argillaceous dolomite with Cystoseira and a characteristic assemblage of foraminifera were found by us at the top of the so-called Abadzekh zone of S.T. Korotkov [1].

Thus, the Alkun carbonate rocks with Cystoseira may be safely used in correlating widely separated sections, in comparing local schemes of subdivision of the Maikop series and in working out a unified stratigraphic section of these sediments.

REFERENCES

1. GEOLOGIYA SSSR. T. 9. SEVERNYY KAVKAZ. CH. I. GEOLOGICHESKOYE OPISANIYE [GEOLOGY OF THE U.S.S. V. 9. NORTHERN CAUCASUS. PT. 1: GEOLOGICAL DESCRIPTION]: Gosgeoltekhizdat, 1947.

2. Gubkin, I.M., MAYKOPSKIY NEFTENOSNYY RAYON. NEFTYANO-SHIRVANSKAYA NEFTENOSNAYA PLOSHCHAD' [MAIKOP PETROLIFEROUS REGION. NEFTYANOSHIRVANSK PETROLIFEROU AREA]: Tr. Geol. kom-ta, nov. ser., vyp. 78, 1912.

Dmitriyeva, R.G., TIPY GLIN MAYKOPSKOY SERII VOSTOCHNOGO PREDKAVKAZ'YA I IKH FATSIAL'NAYA PRIUROCHENNOST' [TYPES OF CLAYS IN THE MAIKOP SERIES OF EASTERN CISCAUCASIA AND THEIR DISTRIBUTION AMONG THE FACIES]: Tr. Soveshch. po mineralogii i petrografii osadochnykh porod. Izd. Akademiya Nauk Azerb. S.S.R., 1958.

Prokopov, K.A., ALKUN-ASSINSKIY RAYON (INGUSHETIYA, SEVERNYY KAVKAZ) [THE ALKUN-ASSA REGION (INGUSHETIYA, NORTHERN CAUCASUS)]: Tr. Geol Sluzhby Groznefti, vyp. 5, 1936.

__________, OCHERK GEOLOGICHESKIKH OBRAZOVANIY PO R. KUBANI MEZHDU SULIMOVYM I KRASNOGORSKOY [DESCRIPTION OF FORMATIONS ALONG THE KUBAN' RIVER BETWEEN THE VILLAGES OF SULIMOVA AND KRASNOGORSKAYA]: Tr. Geol. sluzhby Groznefti, vyp. 8, 1937.

6. Prokopov, K.A. and A.A. Khutsiev, MAYKOPSKAYA SVITA V SULAKSKOM RAYONE [THE MAIKOP SERIES IN THE SULAK REGION]: Tr. Sev.-Kavkazsk. konf. geologov-neftyanikov, vyp. 5, 1933.

7. Shatskiy, N.S., GEOLOGICHESKOYE STROYENIYE VOSTOCHNOY CHASTI CHERNYKH GOR I NEFTYANYYE MESTOROZHDENIYA MIATLY-DYLYM [GEOLOGICAL STRUCTURE OF THE EASTERN PART OF THE BLACK MOUNTAINS AND THE MIATLY-DLYLYM PETROLEUM DEPOSIT]: Tr. Geol. in-ta, vyp. 4, 1929.

Groznyy Petroleum Research Institute

Received July 9, 1958

LOWER SILURIAN DEPOSITS OF SOUTHEASTERN TRANSBAIKALIYA [1,2]

by

V. N. Kozerenko and A. A. Lokerman

The fact that many deposits in the polymetallic belt of Eastern Transbaikaliya are localized in the Lower Paleozoic rocks makes the investigation of these strata particularly important.

As a result of geologic mapping in 1946-1951 (by D.I. Gorzhevskiy, N.S. Gorshkov, E.M. Laz'ko, G.B. Mitich, A.F. Mushnikov and others), the Lower Paleozoic series of southeastern Transbaikaliya was divided into the following conformable formations [1]:

1) the Bystrinsk formation, with an exposed thickness of 1000 to 1200 meters, composed of limestones, dolomitic limestones, beds of phyllite, and locally shales at the base;

2) the Altacha formation, about 2000 meters thick, composed of argillaceous shales, phyllites and siltstones, with beds of limestone sandstone;

3) the Nerchinskiy-Zavod formation, up to 2000 meters thick (up to 1500 meters, according to new data), composed of dolomites and dolomitic limestones with beds of argillaceous marly shales; and

4) the Blagodatskiy argillite formation, with beds of quartzites and limestones and a thickness of 600 meters.

The thick carbonate sequence which occurs in the lower part of the section in many places in southeastern Transbaikaliya (the Argun' River region) was referred to the Bystrinskiy formation on the basis of comparison with the standard section in the Gazimurov Zavod region, where this formation was first defined. There it occupies an analogous position in the section and on the basis of its archaeocyathid fauna is referred to the Lower or Middle Cambrian.

The age of the Altacha and of the lower part of the Nerchinskiy-Zavod formations was formerly believed to be Lower Cambrian-Ordovician on the basis of the finds of blue-green algae and also because the overlying Blagodatskaya formation contains characteristic Silurian fauna.

It should be noted that at first [2] the Blagodatskaya formation was considered as resting unconformably on Lower Paleozoic rocks, but after Gorshkov's investigation the idea of its conformity with the underlying strata was generally accepted. This formation was known from one small area only, and therefore, in spite of its very characteristic lithology (brightly colored argillites), could not be used as a key formation in mapping.

The Bystrinskiy, Altacha and Nerchinskiy-Zavod formations are widely distributed in southeastern Transbaykaliya. The absence of faunas and of reliable key beds and the presence of overturned folds masking the actual age sequence make the mapping of these formations very difficult and often introduce inaccuracies into the stratigraphic sections.

Some investigators doubt the presence in southeastern Transbaykaliya of two carbonate formations of different ages and the existence of the Nerchinskiy-Zavod formation is either denied or else it is combined with the Blagodatskiy formation.

Recently obtained data show that these ideas have no basis, confirm the accepted stratigraphic section, and introduce a few corrections into it.

That the very thick limestone beds at the base of the Lower Paleozoic series belong to the Bystrinskiy formation was proved beyond doubt in 1957 when G.I. Knyazev, S.P. Kruzir

---

[1] O nizhnesiluriyskikh otlozheniyakh yugovastochnogo zabaykal'ya.

[2] This article, in an abbreviated form, was published in Doklady of the Academy of Sciences, USSR, v. 123, no. 6, 1958. Through no error of the authors, in the title and in many places in the text, the phrase "Lower Silurian deposits" was replaced by "Ordovician deposits" and the term "Lower Paleozoic series" by "Ordovician series."

ıd others found abundant remains of archaeo-
yathids in the carbonate beds near the village
 Georgievka (northwest of Nerchinsk mill)
hich were formerly assigned to the forma-
on on indirect evidence only.

In the Altacha formation at a number of
ıcalities spores and pollen have been found
hich, in the opinion of Yu. A. Alyushinskiy
ıd E.Z. Isagulov, are characteristic of the
pper half of the Cambrian.

The most conclusive evidence for the solu-
on of the debatable questions of Lower Paleo-
oic stratigraphy was the discovery by Loker-
ıan and Parkhomets in 1957 of a fauna which
roves that the upper part of the Nerchinskiy-
avod formation is Lower Silurian. Before
ıat, no faunas were known from this forma-
on, and the presence of Lower Silurian beds
 southeastern Transbaykaliya was assumed
ut not proved. It was shown at the same
me that the view that the Blagodatskiy for-
ıation rests conformably on the Nerchinskiy-
avod formation and is of Silurian age is
rroneous.

Let us review the facts on which these
onclusions are based.

The fauna of the Nerchinskiy-Zavod forma-
on was found on Mt. Blagodatskaya 10 kilo-
ıeters south of Nerchinskiy Zavod, in the
outhwestern part of a large exposure, in a
rge syncline complicated by minor folds and
ults. The predominant rocks of the forma-
on are light-gray dolomitic limestones and
olomites, usually cryptocrystalline or fine-
rained, and frequently silicified. Much less
bundant are dark, carbonaceous and marly
mestones. Lenses of dark-gray, reddish
nd greenish argillaceous and marly shales
p to 70 to 80 meters in thickness occur
ccasionally in different parts of the section,
ut most commonly in its lower part, where
ıey are usually dark and rich in carbonaceous
ıatter, and its upper part, where light-
olored marly shales predominate. In the
erchinskiy-Zavod area of carbonate rocks
ıere are several thin beds of conglomerate
omposed of well rounded pebbles of carbonate
ocks and arenaceous-calcareous cement. The
xposed thickness of the Nerchinskiy-Zavod
ormation in this region is not over 1500
ıeters.

The Mt. Blagodatskaya area where the
una was found has a very complex structure.
 is the only place in the Argun' River region
here in a narrow zone, which according to
ıe geologic map is a down dropped block of
ıe axial part of a syncline bounded by faults,
lmost the entire upper part of the Lower
aleozoic section can be seen, i.e. the Ner-
hinskiy-Zavod, Blagodatskiy and Verkhnyaya
orzya formations (the age of the last named
being within the D_3-C_1 interval).

According to geologic maps, the upper part of the Nerchinskiy-Zavod formation is exposed in this region and contains the following rocks:

1. Massive, gray dolomitic limestones, locally silicified and usually fine-grained. The exposed thickness is over 2000 meters (including borehole data).

2. Argillaceous shales, thin, gray and dark-gray, with occasional layers enriched in carbonaceous and clastic material; thirty to forty meters in thickness.

3. Massive gray dolomitic limestones identical with those at the base of the section and up to 150 meters in thickness.

4. Marly thin-bedded reddish limestones, platy; twenty to forty meters thick.

The limestones merge gradually into:

5. Marly and argillaceous-marly reddish and greenish-gray shales with exposed thickness of fifty meters. The shales contain lenses of light-gray dolomitic limestone and of conglomerate composed of well rounded limestone pebbles and shale fragments, cemented with arenaceous-argillaceous material containing small shell fragments. In places the rock becomes a coquina with a few pebbles.

In the upper part of the section, in the marly shales and in the layers of coquina and limestone conglomerate, the following fossils have been found: Tuvaella rackovskii Tschern., Dalmanella sp., Leptaena cf. rhomboidalis Wilck., Stropheodonta sp., Stegerhynchus decemplicatus Sow. var. angasiensis Tschern., Camarotoechia sp., Atrypa sp., Spirifer cf. pedaschenkoi Tschern., S. sp., Eospirifer sp.

The fossils were identified by Ye. A. Ivanova and independently by O.N. Nikiforova and V.E. Kyrvel, and were unanimously assigned to the Wenlockian stage of the Lower Silurian.

Let us consider the evidence that the beds containing this fauna belong to the Nerchinskiy-Zavod formation.

From the main area of the development of this formation the area of Mt. Blagodatskaya is separated by a saddle up to 200 meters in width. The limestones outcropping on the mountain are lithologically indistinguishable from those on the south side of the saddle and all investigators agree that they belong to the Nerchinskiy-Zavod formation. Now that a tunnel has been excavated between the Blagodatskaya and Yekaterino-Blagodatskaya

mines under the saddle, the continuity of the limestones beneath the Quaternary cover of the saddle has been proved, together with the fact that the Blagodatskaya area represents the margin of the Nerchinskiy-Zavod limestone exposures.

All beds lying above the Mt. Blagodatskaya section are conformable with each other, strike nearly east-west, and dip steeply to the south.

Both the attitude and the lithology of these rocks indicate that they belong to one structure. Let us recall that layers of marly shales and conglomerates are known also in other exposures of the Nerchinskiy-Zavod formation.

It is important to note that all investigators who have made detailed studies and exploratory work in the Blagodatskoye deposit (K.D. Sholkin, and L.N. Lenok, K.F. Kuznetsov, A.N. Svirskiy and others) have remarked on the gradual change from the thin-bedded marly limestones to marly shales containing Wenlockian fauna and, in this locality, lying at the top of the Nerchinskiy-Zavod formation.

The recent additional mapping by M.I. Stetsyuk on 1:1000 scale shows that the fossiliferous zone and other carbonate beds in the marly shales repeat the outline of the thin-bedded marly limestone zone and have the same attitude. Thus, all available data definitely indicate that the section is continuous and the defined zones conformable.

Important additional data indicating that the fossiliferous zone of Mt. Blagodatskaya and the underlying thick limestone sequence forming the Nerchinskiy-Zavod syncline are of the same age are provided by the analysis of the spore-pollen assemblage.

It is important to emphasize that the spore assemblage from the fossiliferous zone is identical with the spore spectrum characterizing the upper parts of the Nerchinskiy-Zavod formation. The following spores were identified in the different outcrops of the formation (Gornyy Zerentuy, Ol'khovaya gully): Archaoe monoporina incrassa Naum., Stenomarginata minuscula Naum., S. subverruculata Naum., Hystrichosphaeridium glabrum Naum., Psophosphaera tenius Naum., Sphaerina minuta Naum., Palaeoperisaccus decorus Naum., P. explanatus Naum., P. elongata Naum.

According to Ye.Z. Isagulova's conclusion, confirmed by S.N. Naumova, this assemblage is very similar to the spore assemblage of the Bratsk formation (Siberian platform) whose age is Upper Ordovician-Lower Silurian. The data of the spore-pollen analysis agree completely with the paleontological data.[3]

Let us return now to the description of the Mt. Blagodatskaya section.

Stratigraphically above the marly shales containing Wenlock fauna and unconformably upon them lies the Blagodatskiy formation, composed of:

1. Basal beds of quartzites (sandstones and conglomerates) dipping gently (25-35°) to the north and varying greatly in thickness (0 to 30 meters).

2. Varicolored argillite (spotted, violet, reddish-brown, green, brown and light blue) with lenses of strongly silicified limestone; up to 450 meters thick.

3. Grayish-brown siliceous shales (related to the argillites by a gradational transition). Thickness up to 150 meters.

In the argillites the author, and M.I. Stetsyuk, V.E. Kyrvela and others, collected the following fossils: Metriophyllum sp. n., Pleorodictyum, Batostomella sp. n., Eridotrypella sp., Fistulipora sp. n., Paradekayella sp. n., Lioclema sp. n., Semicoscinium sp. and Fenestella sp.

According to I.P. Morozova, Ye.A. Ivanova and N.Ya. Spasskiy, this fauna dates the formation as Middle Devonian (and possibly the upper part of Lower Devonian), while according to Ye.A. Modzalevskaya this fauna characterizes the upper zones of the Lower Devonian (Coblenzian stage) and bears a definite resemblance to the fauna of the upper zones of the Bol'shoi Never formation of the upper Amur region.

As has already been mentioned, the Blagodatskiy formation was formerly considered Silurian and conformable with the underlying Nerchinskiy-Zavod formation. The reason for this error is that Gorshkov took the reddish marly limestones and the overlying shales as the base of the Blagodatskiy formation, probably because their color somewhat resembles that of the argillites of this formation. The thin-bedded limestones and marly shales are actually conformable with the typical "Nerchinskiy-Zavod" massive limestones, but they are not a part of the Blagodatskiy formation. The unconformable attitude and the basal aspect of the quartzite at the base

---

[3] In B.V. Timofeyev's opinion based on the examination of only a few samples from the Nerchinskiy-Zavod formation, it contains also Lower Cambrian, Sinian spores. This conclusion contradicts all paleontological characteristics of the formation.

of the Blagodatskiy formation evidently was not noticed because it was poorly exposed prior to the mining operations. The greater degree of metamorphism of the marly shales lying beneath the quartzite as compared with the overlying argillites apparently also escaped notice.

In 1956, three kilometers south of the Nerchinskiy Zavod settlement, we found a new area of outcrops of the Blagodatskiy formation which also show its unconformable relation to the limestones of the Nerchinskiy-Zavod formation. Finally, the most convincing proof of the existence of disconformity between these formations is the faunal analysis: below the disconformity the fauna is Wenlockian; above it, Middle Devonian.

The presence of a fauna in the marly shales underlying the quartzite was not known to Gorshkov (judging by his description). He collected fossils largely from the talus on the mountain slopes and his collection contains mainly the forms of the Nerchinskiy-Zavod formation, but it was believed that they came from the Blagodatskiy formation where fossils had been found by Gorshkov in situ. The age of the fossils collected by Gorshkov was determined as Silurian by M.A. Bolkhovitinova. This would be correct if the fauna came from the Nerchinskiy-Zavod and not the Blagodatskiy formation. This, in our opinion, is the explanation of the error.

In summary, it may be noted that as a result of very detailed work it has been proved that the Nerchinskiy-Zavod formation, widespread in southeastern Transbaikaliya, is Lower Silurian (Wenlockian). It has been shown also that the attempt to "liquidate" this formation is not justified and would lead to a completely erroneous interpretation of the structures of the region. The age and position of the Blagodatskiy formation have been determined, and this introduces a correction into the accepted stratigraphic section and adds to the knowledge of the history of the region in the Devonian period.

The discovery of faunas in the lower and upper limestone formations (Bystrinsk and Nerchinskiy-Zavod formations, respectively) makes the Lower Paleozoic section of the Nerchinskiy-Zavod region of exceptional importance for the understanding of the structure of the Lower Paleozoic rocks of southeastern Transbaikaliya, and the section must be regarded as a type section.

This region, because of its economic importance, is covered by detailed geologic maps and has been studied by geologists over a long period of time. None of them has found any signs of disconformity in the Lower Paleozoic section and all of them consider it as an uninterrupted section. Now it has been shown by the discovery of faunas that the section was deposited in the interval of time between the Lower Cambrian and Lower Silurian, inclusively. This indicates that the ideas of the absence of Ordovician deposits in southeastern Transbaykaliya are groundless.

Inasmuch as the fossils of the Altacha formation date it within very broad limits, the Lower Paleozoic formations may be indexed at present as follows: Bystrinskiy — Cm_{1-2}, Altacha — Cm_{2-0}, and Nerchinskiy-Zavod — $O\text{-}S_1$.

REFERENCES

1. Kozerenko, V.N., GEOLOGICHESKOYE STROYENIYE YUGO-VOSTOCHNOY CHASTI VOSTOCHNOGO ZABAYKAL'YA [GEOLOGICAL STRUCTURE OF EASTERN TRANSBAIKALIYA]: Izd-vo L'vovsk. gos. un-ta, 1956.

2. Kozerenko, V.N., E.M. Laz'ko and G.B. Mitich, O VOZRASTE DREVNIKH SVIT PRIARGUN'YA (VOSTOCHNOYE ZABAYKAL'YE) [THE AGE OF THE ANCIENT FORMATIONS OF THE ARGUN' REGION (EASTERN TRANSBAIKALIYA]: Izvestiya, ser. geol., Akademiya Nauk SSSR, no. 3, 1949.

All-Union Correspondence Institute
of Polytechnics,
Moscow

Received March 17, 1959

BRIEF COMMUNICATIONS

COMMENTS ON THE 1956 UNIFIED STRATIGRAPHIC SECTION OF THE COAL-BEARING DEPOSITS OF THE KUZBAS[1]

by

I. A. Vyltsan

At the 1954 conference at Leninsk-Kuznetskiy and the 1956 conference at Leningrad, a new detailed and unified stratigraphic section of the coal-bearing strata of the Kuzbas was adopted which, on the whole, gives an objective picture of the rhythmic course of deposition of the coal-bearing strata of the Kuzbas.

Very significant in the 1956 chart is the recognition of the large stratigraphic units, or series, corresponding to the main epochs of coal formation in the basin (based on the sequence of plant assemblages established by M. F. Neyberg [6]) and to the very large tectonic rhythms. Two such rhythms (or cycles) are distinguished in the Upper Paleozoic coal-bearing sequence: The first one includes the deposits of three formations—the Ostrog, the Lower Balakhonka and the Upper Balakhonka—and the second, the Kuznetsk, Il'inskoye and Yerunakovo formations.

As is known, in the first cycle (let us call it the Balakhonka cycle) the Ostrog formation has no minable coal, but the other two, the Lower and Upper Balakhonka formations, contain economic coal deposits. The detail with which the formations are subdivided is in direct proportion to their coal content. In the new chart the Upper Balakhonka formation is subdivided into four members, the Lower Balakhonka, into two, and the Ostrog formation is not subdivided.

The second cycle, which may be named the Kol'chugin cycle, also includes three formations, of which the Kuznetsk formation is barren, the Il'inskoye formation contains coal beds in its upper part, but only in the south, and the Yerunakovo formation is the most productive of all.

It is apparent that the formations of the Kol'chugin cycle have also been studied with varying degrees of detail: the Yerunakovo formation is subdivided into three members; the Il'inskoye, into two, but only in the south; and the Kuznetsk formation is not subdivided at all.

The obvious incompleteness of the 1956 stratigraphic chart is shown by the difference in detail of the subdivision of the formations. The new lithological material on the subdivision of the barren formations collected, for example, by the Siberian Research Institute of Geology, Geophysics and Mineral Raw Materials was not utilized in the construction of the 1956 chart.

The twofold division of the Il'inskoye formation, until recently considered barren, is not adequately documented in the 1956 chart.

Inasmuch as it is known now that the southwestern and southern parts of the Il'inskoye formation contain workable coal beds (Nikitinskoye, Chertinskoye, Raspadskoye and other deposits) the data on its structure are very important for stratigraphy and for the study of the specific conditions of coal formation in the Kuzbas in general and in the Il'inskoye formation in particular.

In the 1956 unified stratigraphic section, two members are separated in the Il'inskoye formation—the lower, or Kazankovo-Markinskoye, and the upper, or Uskat member. Actually this subdivision does not fully reflect the relations between the smaller units within the formation and is incomplete to say the least. In the preparation of the now accepted section, attention and "care" were given only to that part of it (upper) which usually contains abundant fossil leaves and the materials available for the subdivision of the lower and

[1] Nekotoryye zamechaniya po unifitsirovannoy stratigraficheskoy skheme uglenosnykh otlozheniy kuzbassa 1956 g.

thicker (but only slightly fossiliferous) part of the section were not used and even ignored, although they provide lithological criteria for subdivision.

To show that this criticism is justified it is necessary to recall briefly the history of the problem of subdivision of the Il'inskoye formation.

The Il'inskoye formation was first divided into three zones in 1943 by Yu. A. Zhemchuzhnikov in a manuscript report, which unfortunately was never published but is well known to the geologists of the Kuzbas. Zhemchuzhnikov described the lithological units of the formation, measured their thickness and named them (base to top): the Markinskoye (600-700 m), the Salair (500-700 m) and the Kazankovsk (350-400 m) zones. The Il'inskoye formation of the Kuzbas is characterized by many facies changes along the strike, and for this reason its sections were not subdivided for a long time. The first subdivision of the formation was made by Zhemchuzhnikov in a typical section outcropping on the left bank of the Tom' River from the village of Kazankova, to the core of the Markinskoye anticline and farther to the Suriyekova River.

The analogues of the Il'inskoye formation in the northern part of the basin, the so-called Krasnoyarsk sandstones, were also subdivided into three zones in 1946 by V.I. Yavorskiy and P.F. Li [10]. Our more recent study (1952-1957) of the Il'inskoye formation, based on the data from test wells drilled in the search for oil and from natural outcrops occurring throughout the basin, confirmed the data of Zhemchuzhnikov, Yavorskiy and Li and provided new material on the lithological changes within the formation and within its different parts.

At the conferences on the stratigraphic section of the Kuzbas in Leninsk-Kuznetskiy in 1954 and in Leningrad in 1956, the division of the Il'inskoye formation into three zones proposed by the above-mentioned authors was not accepted, partly because it was not always possible to provide sufficiently objective paleontological criteria for the smaller subdivisions and partly because in a number of sections in the Salair region and in the south the formation changes in thickness. The so-called "Uskat sequence" and a part of the Suriyekov zone, formerly included in the Yerunakovo formation [2, 4, 9], were assigned to the Il'inskoye formation.

At present it is known quite definitely that the lithological subdivisions of the Il'inskoye formation (Zhemchuzhnikov's zones) can be traced throughout the basin and that the "Uskat sequence" is a facies of the upper part of the formation not only in the center of the basin and in the Salair region, as had been pointed out earlier by G.P. Radchenko [7], E.M. Senderzon [8] and others, but in the extensive area of the southern Kuzbas as a whole. In other words, the sequence represents a series of coal-bearing facies of

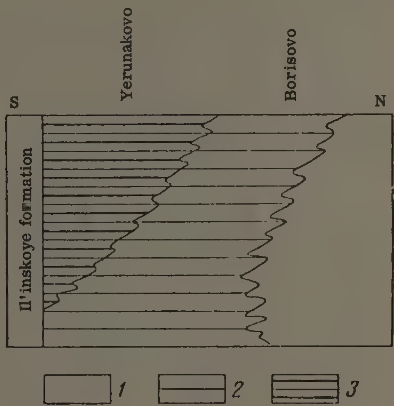

FIGURE 1. The relationship among the principal facies of the Il'inskoye formation of the Kuzbas (after the data of the Siberian Research Institute of Geology, Geophysics and Mineral Raw Materials).

1 -- Krasnoyarsk facies, 2 -- Il'inskoye facies "proper", 3 -- Uskat facies.

the Il'inskoye formation containing workable deposits and characterized by the predominance of the paludal-lacustrine facies over the alluvial facies and by a general thickening of the sediments to the south and southeast. This clearly indicates that the Uskat facies have shifting "boundaries" so that southward the coal beds occur at lower and lower stratigraphic levels. In the sections of the formation on the Verkhnyaya Ters' River and elsewhere the coal beds of workable thickness lie 230 to 300 meters from the base of the formation, while in the northern part of the basin they occur only in the uppermost parts of the formation. The lower "boundary" of the Uskat facies cuts the formation diagonally from north to south (Fig. 1).

The actual relationship between the Uskat facies (formerly called "Uskat sequence") and the facies of the other parts of the Il'inskoye formation speaks against separating them as an independent stratigraphic unit or member, first, because they contain sediments differing in age and, second, because their

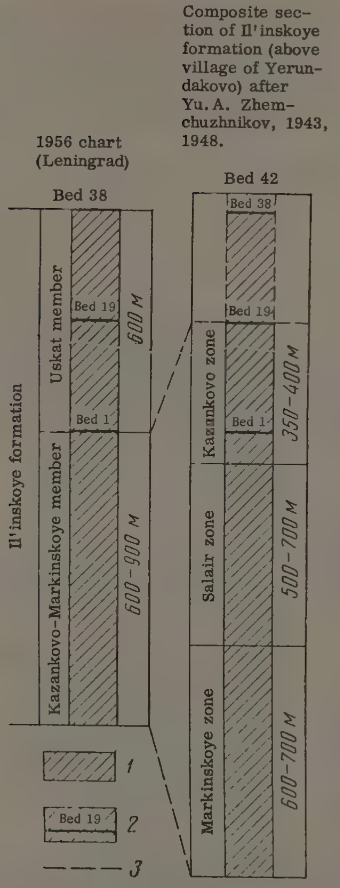

FIGURE 2. Comparison of the subdivisions of the Il'inskoye formation after Yu.A. Zhemchuzhnikov and after the 1956 Conference in Leningrad.

1 -- Rocks of the formation; 2 -- coal bed; 3 -- correlation lines.

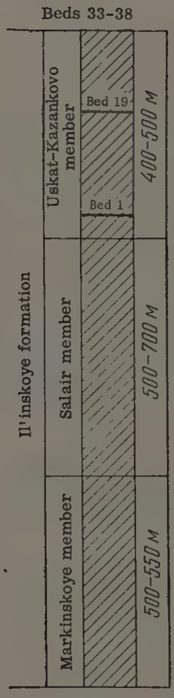

FIGURE 3. Subdivision of the Il'inskoye formation proposed in this paper.

separation as a unit would exclude synchronous deposits of the upper part of the formation (Kazankino zone).

There are also objections to the content and the names of the subdivisions of the Il'inskoye formation, the Uskat and the Kazankovo-Markinskoye members given in the 1956 chart.

The nature of the Uskat beds or facies has just been explained and it is clear that the introduction of the "new" stratigraphic entity, the Uskat member, must inevitably lead to confusion between the concepts of facies, stratigraphic unit and so on, and cause all kinds of misunderstandings.

Before the conference of 1954, the Uskat beds (together with the Kil-chigiz beds) in the outcrops on the Tom' River above the village of Yerunakovo included, according to N.M. Belyanin [3], the group of beds up to coal bed 19. In the 1956 chart, the thickness of

this subdivision, now given the rank of member, was approximately doubled by the addition of zone 'b' [4] and defined as the sequence of strata between coal beds 19 and 38 [9]. This suggests that the authors of the project accepted in 1956 were led to increase the thickness of the unit because of the lithological resemblance of the rocks between beds 19 and 38 to the rest of the Il'inskoye formation noted by Zhemchuzhnikov [5] and later pointed out by Gorelova [4] and others. Moreover, the retention of the old name "Uskat" for the member, whether so intended by the authors or not, creates the impression that this step was made in order to give the Uskat member at least a semblance of a regional stratigraphic unit in the central and southern parts of the basin. But since the subdivisions of the formation were given different content in the 1956 chart, it is questionable whether it was advisable and justifiable to retain the names of the old subdivisions — Kazankovo-Markinskoye and Uskat.

Inasmuch as the subdivisions of the Il'inskoye formation include all of Zhemchuzhnikov's zones, it is necessary to consider what is included in the Kazankovo-Markinskoye member. This member (in the 1956 chart) is equivalent to the Il'inskoye formation of the old subdivision (1954); i.e., it includes all strata from the top of the Kuznetsk formation to bed 19, and according to Zhemchuzhnikov's later work, even to beds 30-41 [5]. The thickness of this part of the section was estimated at 1400 to 1600 meters. In the 1956 chart, however, the upper boundary of the Kazankovo-Markinskoye member, for some unknown reason, is set at bed 1, which lies at least in the lower part of Zhemchuzhnikov's Kazankovo zone. It is hard to see why a member should be called Kazankovo-Markinskoye if almost all of the Kazankovo zone is included in the overlying Uskat member. Inasmuch as the Kazankovo-Markinskoye member figures in the 1956 scheme as a synonym for the Kazankovo-Markinskoye zones of Zhemchuzhnikov (this is confirmed by the name of the member), the member will be understood to have the content assigned to it by this author. It follows quite logically from this that the part of the section about 300 meters thick from bed 1 to bed 19 actually appears twice in the 1956 chart, as can be seen by comparing this chart with Zhemchuzhnikov's section (see Fig. 2).

An objective analysis of the extensive material obtained by the present author and kept at the Siberian Research Institute of Geology, Geophysics and Mineral Raw Materials confirms the data of Zhemchuzhnikov and Yavorskiy leading to the threefold subdivision of the Il'inskoye formation. The new position of the upper boundary of the Il'inskoye formation (bed 38 of the Yerunakovo section) in the now accepted chart, drawn according to the data of G.P. Radchenko [1], S.G. Gorelova and others [4], confirms once more the correctness of the ideas of Zhemchuzhnikov, who placed the boundary in this position long ago.

Thus, on the basis of the available material, the threefold division of the Il'inskoye formation must be accepted as the most objective and consonant with all geological evidence. The two lower subdivisions which have been traced now throughout the basin should retain their old names but be advanced to the taxonomic rank given them in the 1956 chart; i.e., they should be called the Markinskoye and the Salair members, but the upper subdivision, because of the situation just described, should be called the Uskat-Kazankovo member, inasmuch as it now contains the Uskat beds and a part of the Kazankovo zone. Then the subdivisions of the Il'inskoye formation will be as shown in Figure 3.

It seems to us that the time has come to utilize the considerable material now available on the subdivision and structure of the Il'inskoye and other barren formations of the Kuzbas on the new stratigraphic sections.

REFERENCES

1. Andreyeva, E.M. and G.P. Radchenko, KORRELYATSIYA I UNIFIKATSIYA STRATIGRAFICHESKOGO PODRAZDELENIYA VERKHNEPALEOZOYSKIKH OTLOZHENIY YUZHNOY SIBIRI PO PALEOBOTANICHESKIM DANNYM [CORRELATION AND STANDARDIZATION OF STRATIGRAPHIC SUBDIVISION OF THE UPPER PALEOZOIC STRATA OF SOUTHERN SIBERIA ON THE BASIS OF PALEOBOTANICAL DATA]: Tez. dokl. Mezhved. soveshch. po razrab. unif. stratig. skhem Sibiri, Gostoptekhizdat, 1956.

2. Belyanin, N.M. and L.L. Khalfin, STRATIGRAFICHESKAYA SKHEMA KUZBASSA PRINYATAYA SOVESHCHANIYEM 1954 G. [STRATIGRAPHIC CHART OF THE KUZBAS ACCEPTED BY THE 1954 CONFERENCE]: Vopr. geol. Kuzbassa, t. 1, Ugletekhizdat, 1956.

3. Belyanin, N.M., RASCHLENENIYE I PARALLELIZATSIYA RAZREZOV YERUNAKOVSKOY SVITY KUZBASSA [SUBDIVISION AND CORRELATION OF THE SECTIONS OF THE YERUNAKOV FORMATION IN THE KUZBAS]: Vopr. geol. Kuzbassa, t. 1. Ugletekhizdat, 1956.

4. Gorelova, S.G. and L.L. Dryagina, OPORNYYE STRATIGRAFICHESKIYE

RAZREZY VERKHNEGO PALEOZOYA KUZBASSA PO DANNYM NOVYKH RABOT ZAP.-SIB. GEOL. UPR. [UPPER PALEOZOIC TYPE SECTIONS OF THE KUZBASS ACCORDING TO THE RECENT WORK OF THE WEST-SIBERIAN GEOLOGICAL ADMINISTRATION]: Tez. dokl. Mezhved. soveshch. po razrab. unif. stratig. skhem Sibiri. Gostoptekhizdat, 1956.

5. Zhemchuzhnikov, Yu. A., K VOPROSU O GRANITSE MEZHDU YERUNAKOVSKOY I IL'INSKOY PODSVITAMI KUZNETSKOGO BASSEYNA [ON THE BOUNDARY BETWEEN THE YERUNAKOVO AND IL'INSKOYE SUBFORMATIONS OF THE KUZNETSK BASIN]: Zap. Leningr. gorn. in-ta, t. 17-18, 1948.

6. Neyburg, M. F., K STRATIGRAFII UGLENOSNYKH OTLOZHENIY KUZNETSKOGO BASSEYNA [STRATIGRAPHY OF THE COAL-BEARING BEDS OF THE KUZNETSK BASIN]: Izvestiya, ser. geol., Akademiya Nauk SSSR, no. 4, 1936.

7. Radchenko, G. P., PALEOBOTANICHESKIYE OBOSNOVANIYA DROBNOGO STRATIGRAFICHESKOGO RASCHLENENIYA UGLENOSNYKH OTLOZHENIY KUZBASSA I NEKOTORYYE DANNYYE K OPRDELENIYU IKH VOZRASTA [PALEOBOTANICAL BASIS FOR THE SUBDIVISION OF THE COAL-BEARING STRATA OF THE KUZBAS AND CERTAIN DATA FOR THE DETERMINATION OF THEIR AGE]: Vopr. geol. Kuzbassa, t. 1, Ugletekhizdat, 1956.

8. Senderson, E.M., NOVYYE DANNYYE PO STRATIGRAFII I ELEMENTY PALEOGEOGRAFII PRODUKTIVNYKH SVIT KUZBASSA [NEW DATA ON THE STRATIGRAPHY AND OUTLINE OF PALEOGEOGRAPHY OF THE PRODUCTIVE FORMATIONS OF THE KUZBAS]: Vopr. geol. Kuzbasa, t. 1, Ugletekhizdat, 1956.

9. STRATIGRAFICHESKIY SLOVAR' SSSR [STRATIGRAPHICAL DICTIONARY OF THE U.S.S.R.): Gosgeoltekhizdat, 1956.

10. Yavorskiy, V.I. and P.F. Li, KRASNOYARSKIYE PESCHANIKI KUZNETSKOGO BASSEYNA, IKH RASPRDELENIYE I GENEZIS [THE KRASNOYARSK SANDSTONES OF THE KUZNETSK BASIN, THEIR DISTRIBUTION AND GENESIS]: Materialy po geol. Sibiri, no. 60, 1948.

V.V. Kuybyshev Tomsk State University

Received June 18, 1958

THE OSELKOVOYE FORMATION[2]

by

M.M. Lavrov

In the northeastern part of Eastern Sayan, in the basin of the Bol'shaya Biryusa, Tagul and Tumanshet Rivers, the ancient unmetamorphosed strata consist of four formations (base to top): 1) the Karagassa quartzites, with visible thickness of 400 to 500 meters; 2) the Oselkovoye micaceous sandstones, shales and thin-bedded quartzites, with a thickness of about 4000 meters; 3) the Ust'-Tagul formation, about 110 meters in thickness, composed of conglomerate, sandstone with marlstone and sandstone with limestone; and 4) the Tal'sk limestone, about 300 meters in thickness.

The age of these strata is given differently by different geologists. Some refer the Karagassa formation (or Karagassa and Oselkovoye formations) to the Upper Proterozoic, others consider the Karagassa and Oselkovoye formations as Sinian, and still others refer the entire sequence to the Lower Cambrian.

Without evaluating the merits of these opinions concerning the age of the Biryusa complex, let us mention that it has become a subject of lively discussion in connection with the discovery of a granite intrusion corresponding in time to the disconformity between the Oselkovoye and Karagassa formations[3] and the problem of the separation of the Sinian series in the marginal zones of the Siberian platform. Descriptions of the Biryusa complex are appearing more and more frequently in the geological literature, and some authors refer to the second formation from the base as the Oselkovoye and others as the Oselochnoye formation. It is definitely known that up to 1958 the question of changing the name of the formation from Oselkovoye to Oselochnoye had not been raised. If we refer to the "Stratigraphic Dictionary of the U.S.S.R." [4], we shall read on p. 708: "Oselochnoye formation (Origin of name unknown). Lower Cambrian. (A. Khomentovskiy; Certain Materials on the Geology of the Tumanshetskiy Salt Basin (E. Siberia). Byull. Mosk. obshch. isp. prirody, nov. ser., t. 55, otd. geol., t. 25, v. 3, p. 67." A description of the lithology of the formation follows, and its thickness and position in the section are given. The author of the entry is G. Kirichenko.

---

[2]Ob oselkovoy svite.

[3]P.V. Osokin's report at the Scientific Session of the A.A. Zhdanov Irkutsk University in March of 1958.

What caused Kirichenko to change the name of the formation from Oselkovoye to Oselochnoye?

Let us turn to Khomentovskiy's paper cited by Kirichenko. This paper [5] is on p. 65 and not on p. 67. The name "Oselkovoye formation" is mentioned in it 26 times (!), on pp. 66-69, 71-73 and 75-77, and the name "Oselochnoye" not once.

Had Kirichenko read Khomentovskiy's paper he would not have made these two mistakes.

Where, then, did the name "Oselochnoye formation" of "unknown origin" come from?

The geologists who follow the literature on East Siberian geology know the origin of this name.

In 1953 a paper by V.T. Mordovskiy, Ye. V. Kravchenko and S.F. Fedorov [2] was published in which the name "Oselochnoye formation" appeared for the first time ([2], p. 11, and others). A justifiably unfavorable review of this work was given by M.M. Odintsov and Ye.V. Pavlovskiy [3]. Mordovskiy, Kravchenko and Fedorov distorted the name of the Oselkovoye formation and changed it to "Oselochnoye."

In 1957, following the example of these authors, another group of authors, five men this time, reproduced this mistake 9 [1], p. 17, 18). Kirichenko, without looking up Khomentovskiy's paper, relied on the authority of such geologists as Mordovskiy and his co-authors and I.P. Karasev and co-authors, and was led into error by two published works, alike, it must be said, in quality.

In saying that the origin of the name "Oselochnoye" is "unknown," Kirichenko evidently meant that the meaning of this name is not known.

The following information is available on this point: in the 90's of the last century, when the Tumanshetskiy salt-extraction plant was active, the local population made "oselki" (whetstones) out of the dense shales of the formation, and hence it received the name "Oselkovoye."

It should be noted that the name "Oselkovoye" formation was known before 1950. In 1937, Khomentovskiy, in mapping the geology of the Tumanshet, Tagula and Bol'shaya Birysa River valleys, used the name Oselkovoye formation (in an unpublished work).

It seems inadvisable to change formational names arbitrarily. Unfortunately, Mordovskiy et al [2] and Karasev et al [1] did not bother to familiarize themselves with the original sources and by their word making caused an incorrect name of the formation ("Oselochnoye") to appear not only in the "Stratigraphic Dictionary of the U.S.S.R." but in many professional and research reports of the Vostsibneftgeologiya, the East Siberian Affiliate of the Academy of Sciences, the Irkutsk Geological Administration, the Sibgeolneruda and the A.A. Zhdanov Irkutsk University.

A correction must be made in the new edition of the "Stratigraphic Dictionary of the U.S.S.R." and the formation called "Oselkovoye" as demanded by priority [5] and the origin of its name.

REFERENCES

1. Vasil'yev, V.G., Ye.N. Kalenov, I.P. Karasev, Ye.V. Kravchenko and M.M. Mandel'baum, GEOLOGICHESKOYE STROYENIYE YUGA SIBIRSKOY PLATFORMY I NEFTENOSNOST' KEMBRIYA [GEOLOGICAL STRUCTURE OF THE SOUTHERN PART OF THE SIBERIAN PLATFORM AND THE OCCURRENCE OF PETROLEUM IN ITS CAMBRIAN STRATA]: Vost.-Sib. gos. geol. trest (Vostsibneftegeologiya). Gostoptekhizdat. 1957.

2. Mordovskiy, V.T., Ye.V. Kravchenko and S.F. Fedorov, GEOLOGICHESKOYE STROYENIYE YUZHNOY CHASTI SIBIRSKOY PLATFORMY [GEOLOGICAL STRUCTURE OF THE SOUTHERN PART OF THE SIBERIAN PLATFORM]: Izd. Akademiya Nauk SSSR, 1953.

3. Odintsov, M.M. and Ye.V. Pavlovskiy, O KNIGE V.T. MORDOVSKOGO, V.V. KRAVCHENKO AND S.F. FEDOROVA "GEOLOGICHESKOYE STROYENIYE YUZHNOY CHASTI SIBIRSKOY PLATFORMY" [COMMENT ON THE BOOK BY V.T. MORDOVSKIY, V.V. KRAVCHENKO AND S.F. FEDOROV "THE GEOLOGICAL STRUCTURE OF THE SOUTHERN PART OF THE SIBERIAN PLATFORM"): Izvestiya, ser. geol., Akademiya Nauk SSSR, no. 2, 1954.

4. STRATIGRAFICHESKIY SLOVAR' SSSR [STRATIGRAPHIC DICTIONARY OF THE U.S.S.R.]: Gosgeolizdat, 1956.

5. Khomentovskiy, A.S., NEKOTORYYE DANNYYE PO GEOLOGII TUMANSHETSKOGO SOLENOSNOGO RAYONA (VOSTOCHNAYA SIBIR') [CERTAIN DATA ON THE GEOLOGY OF THE TUMANSHETSKIY SALT-BEARING REGION (EASTERN SIBERIA]: Byul. Mosk. o-va

ispyt. prirody, nov. ser., otd. geol., t. 55, vyp. 3, 1950.

MARIE STOPES[4]

The well known English scientist and founder of modern coal petrography, Marie Carmichael Stopes, D.Sc., Ph.D., died on October 2, 1958. She was a member of the London Geological Society, the Linnaean Society and the Royal Literary Society.

Marie Stopes was born in 1880 to the family of the English archeologist H. Stopes. She was educated at the University College in London, at the University of Munich in Bavaria, and in 1907-1908 studied botany at the University of Tokyo. In 1904 she began to teach botany at the University of Manchester and in 1909 at the University College in London.

In 1908 Marie Stopes published a paper on the formation of concretions ("coal balls") in coal beds and in 1910 a paper on plant fossils. Her first works on coal petrography appeared between 1918 and 1919.

In appraising these investigations, Yu.A. Zhemchuzhnikov wrote in 1934: "The turning point in the development of coal science was the year 1919 when the English scientist Marie Stopes in a short but epoch-making paper distinguished four components or ingredients in the English banded coals visible with the naked eye and easily separated mechanically (fusain, clarain, durain and vitrain)."

It should be noted that by 1919 the concept of coal constituents had already been formulated in different countries. As early as 1887, H. Fayol, in France, in studying the coals of the Commentry basin, distinguished bright, dull and fibrous coal. In Germany these constituents were also known and German investigators consider that Marie Stopes merely gave them new names. In 1914, in Russia, M.D. Zalesskiy described bright, dull and fibrous coals. It must be acknowledged, however, that it was only after Stopes' studies that a unified terminology and the method of describing these constituents became established. As the result a connection was revealed between the macroscopic and microscopic characteristics of coals and the need for separate chemical study of their constituents realized. This, in effect, laid the foundation of coal petrography, i.e., of the study and description of coals as rocks.

The achievement of Marie Stopes in the detailed study of coals was due to the perfecting of the technique of preparation of thin sections of coal by the English paleobotanist J. Lomax in 1911.

In 1935 Stopes published a paper refining the earlier nomenclature and in the same year, at the Second International Geological Congress on Carboniferous Geology, in Heerlen (Holland), it was proposed by S. Sayler that this nomenclature be accepted with certain modifications. In this nomenclature the constituents of coal are called macerals (by analogy with minerals) and include fusinite, vitrinite (collinite and tellinite), resinite, exinite, micrinite and opaque matter, while the names of the constituents distinguished by Stopes earlier are used to designate the types of coal: fusain, vitrain, clarain and durain. This nomenclature is now known as the Stopes-Heerlen system.

Thus it must be considered the during the past forty years the works in coal petrography have been developing the ideas of Marie Stopes. Only the paper read by Marie Stopes at the Congress on Fuels in Paris in 1923 is available in Russian in the volume "Fuel" published in 1925. However, her main works in the original English are widely known among Soviet coal petrographers.

Besides scientific works in paleobotany and coal petrography, Marie Stopes has written on social problems, marriage, upbringing of children, etc. Her published work includes books on the problem of the family and several novels, plays and poems.

S.I. Tomkeyev (S.I. Tomkeieff, Newcastle upon Tyne, England)
V.S. Yablokov (Moscow, U.S.S.R.)

[4] Mariya stops.

REVIEWS AND DISCUSSIONS

THREE NEW BOOKS ON THE GEOLOGY OF ROMANIA[1, 2]

by

V. Ye. Khain

After the establishment of the people's government, geological investigations in Romania developed with unprecedented scope. Much has already been accomplished: new economic mineral deposits and particularly new petroliferous regions have been discovered. The success of practical geology can not be separated from the development of geology as a science. A clear indication of progress in this direction is the appearance within a short time of three comprehensive works on the geology of the republic.

"Stratigraphic Geology" was written by Academician G. Macovei, most eminent and oldest of Romanian geologists and director of the Geological Committee on the Romanian People's Republic. This is the second edition of the textbook, which has achieved popularity not only in the author's native land but also abroad (the book has been translated into Chinese). Considerable space in Macovei's text is given to a description of the distribution and character of each of the geological systems in Romania, so that it is not only a text of general stratigraphy but of the stratigraphy of Romania as well. The presentation of material is exceptionally clear and is accompanied by fine illustrations and lists of fauna and flora, and the local material fits well into the general review of the geologic systems. This discussion also is very successfully presented. The author emphasizes the principal features of each system resulting from tectonics and the environment of deposition and avoids overloading his book with facts such as make Gignoux's classical Stratigraphic Geology a reference work rather than a textbook. The essential information on the fauna and flora of each period is accompanied by well executed illustrations of guide fossils.

The account of the stratigraphy and paleogeography of Romania, which occupies almost one third of the book, is clearly summarized in a series of stratigraphic charts. At the end of the major sections (Precambrian, Paleozoic, Mesozoic and Cenozoic) there are references to the most important works on the geology of Romania. All this makes Macovei's book not only one of the world's best textbooks of historical geology but also an excellent introduction to the geology of Romania. It is not surprising that Academician Macovei's work was awarded the highest State prize.

An excellent account of the geological structure of Romania is given in "Geology of the Romanian People's Republic" by N. Oncescu, Professor at the University of Bucharest. The discussions in this book are arranged according to regions. A brief introductory chapter on the general tectonic framework of the country is followed by chapters on the structure of the principal tectonic zones. These zones are: the Moldavian platform (the margin of the ancient Russian platform), Dobrudja (a Hercynian structure), the Romanian plain (a young platform), the Eastern Carpathians, the Southern Carpathians, the Walachian basin, the Apuseni Mountains and the Transylvanian and Pannonian basins. The description of the structure of the Romanian Carpathians is preceded by a discussion of the structure of the Carpathian arc as a whole and of its principal subdivisions. Between the chapters "The Eastern Carpathians" and "The Southern Carpathians," the youngest volcanic structures of the inner part of the Eastern Carpathians (the Harghita-Caliman belt and others) are described.

The chapters vary somewhat in plan, depending on the type of structure discussed

---

[1] Tri novyye knigi po geologii rumynii.

[2] G. Macovei. Geologie stratigrafica. Editura tehnica, Bucuresti, 1958. N. Oncescu. Geologie din Republica Populara Romina. Editura tehnica, Bucuresti, 1957. J. Bancila. Geologie din Carpati Orientale. Editura tehnica, Bucuresti, 1958.

and on how well it is known, but in general the author observes the following order: general description of relief and main geomorphic subdivisions, stratigraphy, tectonics and principal mineral deposits. The book contains many stratigraphic charts, geologic and tectonic maps and geologic and stratigraphic sections, which help the reader to understand the factual material and the principal conclusions. The list of 287 important works on the geology of Romania and the detailed index are among the commendable features of the work. The book is accompanied by a 1:2,000,000 generalized geologic map of Romania.

A great merit of Oncescu's book is the objectivity with which he discusses some of the debatable questions of stratigraphy and especially of tectonics and geologic history. It must be mentioned that he has made significant contributions to the geology of the Eastern Carpathians, especially their southern part. We shall speak later about his views on general tectonics.

Those Soviet geologists who are working in the Ukraine and in Moldavia will find it very useful to know Professor Oncescu's excellent work, also awarded a State prize. The publishers of foreign literature made a very timely decision when they made arrangements for a Russian translation of the second edition of the book now being prepared by Oncescu. It would be desirable to have a fuller discussion of the geological and especially tectonic history of Romania as a whole in the second edition. This will probably require a special chapter. The reviewer has learned from a conversation with the author that he intends to do this and also is preparing a series of paleogeographic maps of Romania. These additions will make Oncescu's book even more valuable.

The very recently published "Geology of the Eastern Carpathians" by J. Bancila is a regional monograph on a very interesting and complex part of the vast Carpathian folded arc giving an up-to-date account of its geological structure. The author divides the Eastern Carpathians into seven longitudinal structural zones: 1) the central (Central Carpathians), 2) the western interior zone (the western interior flysch), 3) the eastern-central zone (the eastern interior flysch), 4) the middle interior zone (the middle interior flysch), 5) the middle interior (the central intermediate and marginal flysch), 6) the exterior zone (the exterior flysch) and 7) the pre-Carpathian zone. The last zone corresponds to the frontal downwarp. Besides this subdivision, a number of superimposed Pliocene intermont depressions (inner basins) are distinguished: the Gheorgheni-Ciucul, the Bretcu-Birsei, the Comanecti and the Prale.

The book is divided into chapters corresponding to the structural and facies subdivisions. In each chapter, stratigraphy, lithology of the sediments and structure of the zone are described in detail. By analyzing stratigraphic sections of each zone, the author distinguishes successive sedimentation cycles. These cycles vary in magnitude from zone to zone and even in different areas of a single zone.

The description of the individual zones is preceded by an introduction outlining the boundaries of the Romanian Eastern Carpathians and the history of geologic investigations in the region. There is also a chapter on the structure of the basement of the Carpathian mountain structure, the general characteristics of the sedimentary cover, the structural and facies subdivision and transverse folds. The author distinguishes three types of basement: the Carpathian, outcropping in the central zone; the Podolian, composed of ancient granites and gneisses; and the Mesesian, composed of green schists of the Dobrudja type. Bancila emphasizes the fact that the Eastern Carpathian geosyncline developed on a heterogeneous basement, the Central Carpathian on one side and the Mesesian on the other. The hypothesis of the ancient upwarp, the Kimmeridgian chain composed of green schists is discussed in detail. The sedimentary mantle of the Eastern Carpathians is divided into three types of sediment — the sediments of the western interior basin, flysch and the sub-Carpathian sediments of the frontal downwarp. The author discusses flysch in great detail, gives the characteristic features of flysch according to Tercier, describes the main types of Carpathian flysch (arenaceous, marl-limestone, conglomeratic, coarse, and the black shale type), and dwells on the methods used in studying it. Unfortunately the author apparently is not familiar with the work of N.B. Vassoyevich, although a certain influence of this work is felt in the section on the study of flysch. Of considerable interest is the discussion of a number of upwarps and downwarps transverse to the general trend of the Eastern Carpathians.

The last very brief chapter contains a description of the Neogene volcanic belt Harghita-Caliman superimposed on the interior part of the Eastern Carpathians.

Bancila's book is accompanied by a number of graphic appendices which have value independent of the text; they include a tectonic diagram of the Eastern Carpathians on 1:1,000,000 scale, geological sections across the entire structure and its "foreland" elucidating their structural relationship, and lithofacies profiles illustrating changes in the composition of the sediments across the Carpathians in passing from one structurao-facies zone into another (but unfortunately with the

ickness not drawn to scale). Besides these ppendices appearing as inserts (except for ie map) at the end of the book, there are iany illustrations in the text, geological maps f individual regions and stratigraphic and eologic sections. The numerous well executed hotographs help make the book attractive.

On the whole, Bancila's book on the East-rn Carpathians is an excellent regional geo-gic monograph which should be of consider-ble interest to Soviet geologists working in ie Soviet Carpathians and the alpine folds of he Soviet Union in general. A condensed ranslation of it into Russian would be very esirable.

However, in this work, as in the first dition of Oncescu's book, there is a serious hortcoming in the treatment of the geological istory of the region. The work would gain onsiderably if it contained facies and isopach naps, at least for some of the larger stages f alpine development of the Eastern Carpath-ans. It is quite evident that compilation of uch maps is the next important problem con-ronting our Romanian colleagues.

On the other hand, the three books on omanian geology reviewed here have three ery commendable features in common.

First of these is the refusal to accept the ltra-nappe concept which pictures the Roman-an Carpathians and Carpathians in general as continuous pile of overthrusts coming from n unknown source. This idea has now been ropped by most Romanian geologists, evi-lently not without the influence of Soviet uthors who have criticized the chariage heory in general. At the same time, Roman-an geologists, including Oncescu and Bancila, dmit the existence in the flysch zone of the Eastern and Southern Carpathians and in the puseni Mountains of overthrusts with rela-ively small displacements of 40 to 50 kilo-neters or perhaps slightly more. The degree of documentation varies for different over-hrusts, but the existence of some of these tructures is well established and confirmed y drilling, particularly in the Tarcau region, vhere the horizontal displacement is at least 5 kilometers (see section on p. 103 of Ban-ila's book). The existence of the Walachian verthrust in the Southern Carpathians, estab-ished by G. Murgoci and studied in detail by . Kodarca, is also well documented.

The second characteristic of the three ooks is that they make use, although not yet ully, of the extremely important information rovided by test boreholes on the Romanian lain. These data confirm the platform char-cter of the plain, the considerable develop-nent of Mesozoic platform deposits and the ery great age of the folded basement.

Romanian geologic science may be congratulated on the appearance of three capital works which provide a clear picture of the geological structure of Romania as a whole and of the Eastern Carpathians in particular and discuss the basic problems of Romanian geology on a high theoretical level.

ON THE METHOD OF LITHOLOGICAL DESCRIPTION OF SECTIONS [3, 4]

by

L. N. Botvinkina

Detailed lithological investigations of sedimentary rocks, and of coal-bearing strata in particular, have revealed many genetic characteristics of rocks which serve as a basis for the determination of their facies and provenance, for paleogeographic reconstructions and for more certain correlation of stratigraphic units of different magnitude, from formations and members to individual thin zones. These detailed investigations augment the field descriptions of geological sections. An objective field description of the rocks and their characteristics is the basic document which remains when the core from which it was made has been discarded or much diminished. Naturally this basic document must be thorough and in harmony with the present level of geological knowledge.

In O.A. Betekhtina's opinion [2], however, the achievements of geology are utilized by only a few investigators, and the lithological descriptions made by field parties are generally very simple. She believes also that detailed descriptions of sections and facies analysis "require much time and can hardly be expected in the everyday work of field parties" ([2], p. 176). Betekhtina maintains that, "At present there is an urgent need for a new, rational method or description of sections on the basis of drill cores," and discusses the essential points of the method she proposes. "The essence of the method," she writes, "is in selecting as the smallest unit of a section not simply a particular lithological variety (for example, fine-grained sandstone) or the interbedding of two or several lithological varieties (for example, of argillaceous sandstone and siltstone), but that lithological variety which possesses a number of

---

[3] O metodike litologicheskogo opisaniya razrezov.

[4] A comment on O.A. Betekhtina's paper, "An experiment in lithological description of cores from the coal-bearing beds of Kuzbas" [2].

structural and other macroscopically detectable characteristics which distinguish it from all other rocks in the section." These rock types are characterized by a number of genetic features (structure, texture, composition, the character of preservation of fossil plants, petrographic-mineralogical composition, various inclusions, the character of cement, color, etc.) which receive letter and figure indexes. As the basis for the description of drill hole sections, Betekhtina suggests that drill cores be described in terms of standard rock types. In other words, she proposes the following procedure as a new method: 1) Separate the rocks according to genetic types and 2) describe the section layer by layer, not according to the rocks, but according to the standard genetic types.

We shall not dwell on the first point, for it contains nothing new: The grouping of rocks into genetic types has been used by a number of investigators. As early as the 30's and 40's, T.N. Davydova and Ts.L. Goldshteyn [4], in studying the Bureya coal basin, gave a detailed characterization of the genetic rock types. It is true, as Betekhtina points out, that by a genetic rock type they meant not a single rock but a group of rocks, and therefore, in her opinion, the types established by them need not be considered. However, Betekhtina's types are also represented by two or more rocks (for example, C_2 is fine-grained sandstone or coarse siltstone; type symbol F_2 indicates interbedding of sandstones and siltstones of different grain size, etc.), and for this reason we see no particular difference between her method and the earlier one.

As the result of her study of the Yerunakov formation in the Leninsk region of the Kuzbas, Botvinkina [3] separated nine genetic rock types and facies, described them in detail and explained the method used in separating them. Betekhtina used this work freely and applied the same method in the Leninsk and adjacent Belovsk region in separating five facies analogous to those described by Botvinkina. Undoubtedly, besides being familiar with Botvinkina's work on the coal-bearing strata of the Kuzbas, Betekhtina knows also the work done in the Donbas by a group of geologists from the Geological Institute of the Academy of Sciences under the supervision of Yu. A. Zhemchuzhnikov and V.S. Yablokov, and in particular, the "Atlas of lithogenetic types of the Middle Carboniferous coal-bearing strata of the Donets basin," which was discussed by Yablokov in 1954 at the conference on the Kuzbas. Thus, the proposal to separate genetic rock types is not new, although Betekhtina does not mention this.

Let us consider now the proposal to reduce the description of rocks (evidently not only cores?) to a list of rock types. Evidently sections must be described by means of indexes (since no time will be saved by a detailed description of each type). Betekhtina does not give an example of such a description, but it follows logically from her article that it would look like this: F_2 = 50 cm; C_1 = 2 m; C_2 = 1 m; F_3 = 10 cm, etc. The letters indicate facies: C - channel facies, F - floodplain facies, etc., and the figures indicate the rock type within the facies).

A description like this would require a detailed lithological study preceded by the recognition and description of all characteristics of each genetic type. Moreover, different regions and different zones of formations will have their own specific features and the rock in a new region may be "like" or "unlike" the established "classical" type. This must inevitably require explanations and additions (and this is no less time consuming than a detailed description, and more obscure) or lead to an artificial fitting of rocks to the standard type, to a "Procrustean bed." This is a harmful procedure.

It must be considered also that in some cases the characteristics of the genetic types of rocks are added to by laboratory work: by microscopic analysis, exact identification of the rocks by mechanical analysis, separation of light and heavy fractions, by various special analyses — chemical, pollen, X-ray, luminescence — and, finally, by facies analysis. All these additional data refine the field identification of the genetic type and sometimes change it. The "index" description of a section unaccompanied by enumeration of the characteristics of its rocks immediately disposes of the possibility of refining the field identification. Finally, it is quite clear that a detailed preliminary study is far from possible in every region and for many purposes it is not necessary.

The main point must not be forgotten, that the description of rocks made by field parties has for its object not only the facies analysis (which is undoubtedly very important) but also the solution of a number of other problems related to prospecting and future exploitation of the coal deposits: the discovery of tectonic dislocations and aquifers, the determination of the strength of the rocks, the stability of the roof and base of the deposits, etc. Therefore, it is absolutely necessary, first of all, to identify the rocks, their structure in each bed, their primary characteristics and their secondary, post-depositional features, such as jointing, slickensides, cleavage, cementation, degree of weathering and so on. Another negative feature of Betekhtina's proposal is that the application of her method must lead, in effect, to splitting the geologists studying a region into two groups, those who investigate

the sedimentary sequence in detail and establish rock types, and those members of the field party who "without cunning thought" accept this information and produce a "highly efficient" description of the section by means of the letter and number symbols.

We cannot accept this. Geologists are taught while still at the student's desk how to recognize the main genetic characteristics of rocks and how to use them in describing geologic sections. There exists an extensive literature on the method of describing rocks, and in particular drill cores from coal-bearing beds, instructions, guides, texts, monographs and other aids. Every one of these publications stresses the need of recording the characteristics listed by Betekhtina. For example, G.F. Krasheninnikov, in his "Instructions for the study and description of coal-bearing strata" [5], gives a list of characteristics to be used in describing different rocks of coal deposits and recommends that lithological descriptions vary in degree of detail, the greatest detail being reserved for the type sections. If identical rocks are encountered, there is no need to repeat the description; but the geologist has the right to write "same" only when he is absolutely certain that the rocks are identical, for even rocks seemingly alike may exhibit different features or alterations unnoticed during a cursory examination. (This should not be forgotten in establishing the genetic types either.)

In the "Instructions for geological mapping and prospecting," recently issued by the All-Union Geological Institute (VSEGEI) [6], it is stated (p. 69) that, "In layer-by-layer description the thickness of each layer must be given, *together with a condensed account of its principal distinguishing and genetically important features*" (Italics ours. L.B.), and more than twenty rock characteristics are enumerated. As has already been mentioned, this list should be enlarged by adding a group of characteristics produced by the secondary processes, by diagenesis, metamorphism, tectonic movements and weathering. These requirements have always been considered necessary and have not frightened anyone by their complexity.

Thus, the proposal to replace the description of the features of each distinctive rock layer by the direct assignment of it in the field to a lithogenetic type is incorrect. Moreover, one should not confuse the statement used to avoid repetition that "layer one is similar to layer two" (this has always been permissible) with the description of a section merely by referring each layer to some previously defined type.

I dwell on this seemingly obvious point because, with the present-day broad development of detailed lithological investigations, the tendency toward such an "improvement" in geological descriptions, with its apparent simplicity, may attract adherents and lead to obviously detrimental results.

The most correct procedure, considering the latest achievements in detailed lithological studies, is as follows:

1. Each section should be described layer-by-layer (as has always been recommended), and the rock in each layer named and its characteristic features recorded.

2. Every geologist working with a field party must not only "record" the features observed in the rocks but also ponder on their geological meaning. Only in this way will he be able to establish different genetic rock types possessing definite assemblages of features. These types may be specific or generalized to various degrees, depending on the purpose and scale of the investigation. The separation of such rock types will undoubtedly lead to a better understanding of the process of sedimentation responsible for a given sequence, to more reliable correlation and to the solution of a number of other problems. It is to be understood that the type section must be described with the greatest care and detail.

3. After a certain stage of familiarity with the section has been reached, it is permissible, if a given rock type stands out clearly, not to repeat the list of its characteristics in detail every time it is encountered but to refer to it by its genetic type index, which itself implies a definite assemblage of characteristics. But even then, in addition to giving its genetic index, it is necessary to name the rock, to describe the kind and scale of stratification in the given layer, the nature of its fossils and all the secondary characteristics it may possess.[5] The reference to type saves a detailed description of composition, sorting, color, structure of the layers, nature of inclusions, etc. But the presence of fossils must be recorded, because although present in the layer they may be absent from the core. Moreover, fossils are of importance not only in facies analysis but in stratigraphy. We shall stress once again that the reference to rock type is useful only when the characteristics of the types are sufficiently well known and have been classified for a given region or stratigraphic zone.

One more conclusion follows from this: It is necessary to carry out such lithological

[5] In investigation done for the purpose of facies analysis only, the description of the secondary features may be omitted.

investigations not only for coal-bearing strata but for other sedimentary deposits as well and to compile for each one an "Atlas of lithogenetic types" which would serve as a guide and reference (just as atlases of faunas for different regions are compiled).

This work has been done in part for coal-bearing basins. There are descriptions of genetic rock types for the Donets, Kuznetsk, Podmosko'vye, Karaganda, Pechora, Bureya and Chelyabinsk basins, for the deposits of Tuva, the Verkhneduyisk formation of Sakhalin Island and, with less detail, for certain deposits of Middle Asia, Georgia, Yakutiya and the Kizelovsk basin. The lithogenetic types recognized in these regions, their distinguishing features and facies characteristics, may serve as the basis for description of the coal-bearing section in these regions, but, I repeat, specific types, new characteristics and even new types may be encountered in any new area to be studied, because the environments of sedimentation are many. Therefore, geologists must not be instructed to reduce their descriptions of sections to a brief list of genetic types as proposed by Betekhtina.

REFERENCES

1. ATLAS LITOGENETICHESKIKH TIPOV UGLENOSNYKH OTLOZHENIY SREDNEGO KARBONA DOENETSKOGO BASSEYNA [ATLAS OF LITHOGENETIC TYPES OF THE MIDDLE CARBONIFEROUS DEPOSITS OF THE DONETS BASIN]: Izd. Akademiya Nauk SSSR, 1956.

2. Betekhtina, O.A., OPYT LITOLOGICHESKOGO OPISANIYA KERNOV BUROVYKH SKVAZHIN UGLENOSNYKH OTLOZHENIY KUZBASSA [A METHOD OF LITHOLOGICAL DESCRIPTION OF CORES FROM THE COAL-BEARING STRATA OF THE KUZBAS]: Tr. Tomskogo un-ta, t. 135, 1956.

3. Botvinkina, L.N., USLOVIYA NAKOPLENIYA UYGLENOSNOY TOLSHCHI V LENINSKOM RAYONE KUZNETSKOGO BASSEYNA [CONDITIONS OF DEPOSITION OF COAL-BEARING STRATA IN THE KUZNETSK BASIN]: Tr. In-ta geol. nauk, vyp. 139, ugol'n. ser. no. 4, 1953.

4. Davydova, T.N. and Ts.L. Gol'dshteyn. VYDELENIYE GENETICHESKIKH TIPOV OTLOZHENIY KAK OSNOVA LITOGENETICHESKIKH ISSLEDOVANIY UGLENOSNYKH TOLSHCH [SEPARATION OF GENETIC TYPES OF SEDIMENTARY ROCKS AS THE BASIS OF LITHOGENETIC INVESTIGATIONS OF COAL-BEARING STRATA]: Tr. In-ta geol. nauk, vyp. 90, ugol'n. ser. no. 2, 1947.

5. Krasheninnikov, G.F., INSTRUKTSIYA PO IZUCHENIYU I OPISANIYU UGELNOSNYKH TOLSHCH [INSTRUCTIONS FOR THE STUDY AND DESCRIPTION OF COAL-BEARING STRATA]: Gostoptekhizdat, 1943.

6. METODICHESKOYE RUKOVODSTVO PO GEOLOGICHESKOY S"YEMKE I POISKAM [GUIDE TO THE METHODS OF GEOLOGIC MAPPING AND PROSPECTING]: Gosgeolizdat, 1954.

ON G.D. AFANAS'YEV AND S.G. TSEYTLIN'S ARTICLE: "PRELIMINARY RESULTS OF INVESTIGATIONS OF RADIOACTIVITY OF ROCKS OF THE NORTHERN CAUCASUS AND THEIR SIGNIFICANCE FOR CERTAIN PETROLOGICAL PROBLEMS"[6,7]

by

N. Ye. Mart'yanov

This paper contains very interesting material on the content of radioactive elements in the igneous rocks of the Northern Caucasus. Investigations of many years have enabled the authors to show convincingly that the total U + Th content in granitic rocks increases from the Lower Paleozoic to the Tertiary.

However, in the concluding part of the paper, in the discussion of the origin of volcanic heat, the authors express very debatable ideas.

For example, on page 26 it is stated: "The fact that the heat flow from the depths of the earth is the same in continental regions and in ocean basins suggests that either the suboceanic 'ultramafic' rocks contain as much U and Th as granites or that, in spite of the seemingly convincing interpretations of geophysical data, the oceanic basins are underlain by granite."

The equality of heat flow on the ocean floor and on continents has been demonstrated by direct measurement. The absence of granite

[6] O stat'ye G.D. Afanas'yeva, S.G. Tseytlin "predvaritel'nyye itogi izucheniya radioaktivnosti gornykh porod severnogo kavkaza i ikh znacheniye dlya nekotorykh problem petrologii."

[7] Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 3, 1958.

eneath ocean floors has also been established y numerous observations carried out over a eriod of years.[8]

Any attempt to contradict these data re-uires a very serious basis. The concept of radioactive origin of the internal heat of he earth is a hypothesis whose correctness s becoming more and more doubtful.

The only conclusion to be drawn from the quality of heat flow on the continents and he ocean floor is that the heat flow is very ittle dependent on radioactive decay.

The authors' assumptions that the ocean loor is underlain by a granitic layer because he heat flow is the same on the continents nd the ocean floor does not follow from the acts. This approach to the problem is pre-letermined in this case by the history of the levelopment of a hypothesis extrapolated into eology from the laboratory. The concept of adioactive origin of the earth's internal heat vas not derived from geological facts but is he result of a series of unsuccessful attempts o explain a multitude of geological phenomena y a single physical fact.

To overcome this main difficulty the uthors dwell particularly on metamict miner-als, and on pages 27-28 remark that, accord-ng to the data in the literature, "metamict minerals are examples of conservation of energy in geologically significant amounts."

It should be noted that the geological sig-nificance of metamict minerals as accumu-lators of radiogenic heat is doubted by many specialists.

For example, F. Birch (1956) writes as follows: "The small amount of energy repre-sented by such phenomena as pleochroic halos, thermoluminescence and metamict mineralization which can remain in storage only at relatively low temperatures is unlikely to be of importance for geothermal problems involving the whole earth" (p. 194).

The statement of F. Daniels is similar: "Energy storage and later release at high temperatures in minerals containing uranium and thorium has been established in thermo-luminescent rocks and in metamict minerals. The first of these seems to be too small to be geologically significant, and the second appears to be limited to rather unusual and comparatively rare minerals" (p. 249).

Thus the main objection to the possibility of accumulation of large amounts of heat by metamict minerals is their rarity.

However, even if we admit that the meta-mict minerals exist in large amounts, we still do not have a good argument for the radioactive origin of the earth's heat. According to Daniels (1956), the release of energy from metamict minerals often requires tem-peratures above 700°C, and according to Kerr and Holland (1951) zircons retain a part of their energy up to the temperature of 950°C.

All this indicates that the explanation of the processes occurring in the crustal and subcrustal depths of the earth must be approached with caution.

COMMENTS ON N.A. YEFIMTSEV'S PAPER "THE QUATERNARY GLACIATION OF WESTERN TUVA AND THE EASTERN PART OF GORNYY ALTAY[9,10]

by

L.D. Shorygin

N.A. Yefimtsev's paper contains debatable and erroneous conclusions which must be dis-cussed in order to prevent the general accept-ance of incorrect ideas concerning the glacial history and the time of neotectonic movements in Eastern Tuva and the Eastern part of Gornyy Altay.

Yefimtsev's main conclusion is that only one moraine exists in Tuva and in the eastern part of Gornyy Altay, indicating that these mountainous regions were glaciated only once. He touches upon the questions of neotectonics in passing and states that, "There is no observable expression of a tectonic phase at the boundary between the eo-Pleistocene and Pleistocene," (p. 65) and refers all neotectonic movements to the Tertiary.

In discussing the eo-Pleistocene sediments, Yefimtsev remarks that the glacial deposits of this time are absent from the territory inves-tigated by him. The eo-Pleistocene moraine found by Ye.N. Shchukina in the valley of the Kubadru River he regards as an alluvial de-posit because it is stratified and contains rounded boulders.

---

[8] The value of the earth's heat flux was actually measured but the conclusion that granites are absent from the ocean floors is a deduction based on com-parison of the elastic properties of different earth shells with those of petrologic rock types. Editors.

[9] Znamechaniya po povodu stat'i N.A. Yefimtseva "O chetvertichnom oledenenii zapadnoy tuvy i vostoch-noy chasti gornogo altaya."

[10] Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 9, 1958.

It appears to us that it is incorrect to regard as alluvial a deposit composed of a mixture of gravel, sand, silt and clay and containing boulders of various sizes in different stages of weathering. As for stratification, it occurs locally in lenticular wedging out layers produced by a slight difference in the sorting of the material and in part by slight differences in the color of the sediment. This kind of stratification is not typical of alluvial deposits but is more like the stratification found in recessional moraines as described by Carruthers [16]. The shape of the boulders also suggests glacial origin, for many of them have one especially well developed flat facet, which gives them the flatiron form typical of glacial boulders. Some of the boulders have glacial striae.

The present author and L.P. Aleksandrova found an eo-Pleistocene moraine in the upper reaches of the Aldy-Ishkin and Shalash rivers and the left tributaries of the Talaylyk River. It is composed of large somewhat weathered boulders and covers an ancient peneplaned surface in the mountains of Western Tuva. The peneplaned surface is incised by glacial troughs containing younger moraines which differ from the eo-Pleistocene moraines in being little weathered and in lying on the valley floors.

Yefimtsev's denial of the existence of eo-Pleistocene glacial features in the Altay Mountains and in Tuva is evidently not an oversight, for the diagnostic features of moraines cited by him on p. 71 differ significantly from those generally accepted. His idea that the moraine material is predominantly angular and shows no orientation is erroneous [15-17]. It is likely that in a number of localities of Western Tuva and Eastern Altay moraines were mistaken by Yefimtsev for deposits of a different origin.

In discussing Pleistocene deposits, Yefimtsev incorrectly defines the position of a characteristic zone of flat carbonate concretions within a lacustrine deposit. He describes this zone from the Chulushman River valley, states that it is contemporaneous with the moraine and assigns the formation of concretions to the last stage of recession of the glacier, which formed, as he believes, but one moraine. In a number of regions of Eastern Tuva the present author and I.I. Belostotskiy (1956) found this key bed of lacustrine sediment beneath the upper moraine or beneath the gravels contemporaneous with the moraine. In many sections in the adjacent regions of Gornyy Altay this bed is found between two moraine zones [10]. Such sections have been described from the valleys of the Kubadry and Chulyshman Rivers.

In Western Tuva, along the valley of the Chingekat River, in alluvium synchronous with the lacustrine deposit, we found clay-peat layers containing pollen, indicating that a mild climate existed at the time of their deposition. A similar pollen assemblage was described from the sediments of the synchronous lacustrine deposit in the Bele sections on Lake Teletsk [2] and at the Bashkaus reservoir.

These facts and the regional development of the lacustrine formation indicate that it is interglacial and was deposited between the times of accumulation of the two Pleistocene moraines. It corresponds to the epoch of synchronous strong recession of ice from Eastern Tuva and the eastern part of Gornyy Altay. Thus, Yefimtsev's belief that there is only one moraine in his region, indicating a single glaciation, is erroneous.

Yefimtsev's idea of the time of neotectonic movements in Tuva and Gornyy Altay must also be questioned. The data collected by us [9] and those recorded in the literature [3-8, 10-12] indicate that neotectonic movements occurred in these regions, not only in the Tertiary, but also in the Quaternary period. The presence of a tectonic phase at the boundary between the eo-Pleistocene and Pleistocene in Western Tuva and Eastern Altay is proved by the dislocation of brown weathered eo-Pleistocene alluvial gravels and fanglomerates. As the result of these dislocations, the eo-Pleistocene gravels in Western Tuva are contorted, cut by neotectonic faults and displaced to different elevations. In the valley of the Khemchik River, near the edges of the Khemchik basin, the eo-Pleistocene gravels lie at the level of the river. Down the river, where it cuts through the Khemchik Range, the gravels lie 400 meters above the river level, and still farther down, they lie on the surface of the 80 meter river terrace.

In other river valleys of western Tuva, it is possible to see that the elevation of the gravels depends on the mobility of the structures cut by the stream. In the mountainous regions representing rising blocks, the eo-Pleistocene gravels form the surface of river terraces 120 meters and more above the stream, while in the basins which are areas of downwarping these deposits are buried under younger sediments and lie beneath the present channel of the river.

In Gornyy Altay, according to Ye. N. Shchukina [10] and O.A. Rakovets [7], besides the dislocations already mentioned there are overthrusts of various Paleozoic strata resting on the eo-Pleistocene gravels. No such severe dislocations have been observed in the younger, Pleistocene deposits. Thus, the eo-Pleistocene-Pleistocene tectonic phase has a clear enough expression. A further confirmation of it is

provided by the deep incision of stream valleys between the eo-Pleistocene and Pleistocene.

The facts cited above do not confirm the conclusions given in Yefimtsev's paper concerning glaciation and neotectonic movements in Western Tuva and Eastern Altay.

REFERENCES

1. Giterman, R. Ye., L.V. Golubeva, Ye.V. Korneva and O.V. Matveyeva, SPOROVO-PYL'TSEVYYE SPEKTRY CHETVERTICHNYKH OTLOZHENIY ZAPADNOY I TSENTRAL'NOY TUVY I IKH STRATIGRAFICHESKOYE ZNACHENIYE [POLLEN SPECTRA OF THE QUATERNARY DEPOSITS OF WESTERN AND CENTRAL TUVA AND THEIR STRATIGRAPHIC SIGNIFICANCE]: Tr. Geol. in-ta Akademiya Nauk SSSR, vyp. 31, 1958.

2. Grichuk, V.P., NEKOTORYYE VOPROSY PRIMENENIYA PYL'TSEVOGO ANALIZA DLYA TSELEY REKONSTRUKTSII FIZIKO-GEOGRAFICHESKIKH USLOVIY [ON THE APPLICATION OF POLLEN ANALYSIS TO THE RECONSTRUCTION OF GEOGRAPHICAL CONDITIONS]: Sov. botanika, no. 2, 1943.

3. Nekhoroshev, V.P., CHETVERTICHNYYE TEKTONICHESKIYE DVIZHENIYA NA ALTAYE [QUATERNARY TECTONIC MOVEMENTS IN THE ALTAY RANGE]: Tr. Sov. sektsiya mezhdunar. assos. po izuch. chetvertichn. perioda, vyp. 4, 1939.

4. Obruchev, V.A., ALTAYSKIYE ETYUDY, CH. 1. ZAMETKI O SLEDAKH DREVNEGO OLEDENENIYA V RUSSKOM ALTAYE [ALTAYAN STUDIES, PT. 1. NOTES ON THE TRACES OF ANCIENT GLACIATION IN THE RUSSIAN ALTAY]: Zemlevedeniye, t. 3, kn. 3, 1914.

5. __________, ALTAYSKIYE ETYUDY, CH. 2. O TEKTONICHESKOM STROYENII RUSSKOGO ALTAYA [ALTAYAN STUDIES. PT. 2. GEOLOGIC STRUCTURE OF THE RUSSIAN ALTAY]: Zemlevedeniy, t. 4, kn. 4, 1915.

6. __________, OSNOVNYYE CHERTY KINETIKI I PLASTIKI NEOTEKTONIKI [MAIN FEATURES OF KINETICS AND PLASTIC DEFORMATION IN NEOTECTONICS]: Izvestiya, ser. geol., Akademiya Nauk SSSR, no. 5, 1948.

7. Rakovets, O.A. and G.F. Lungersgauzen, O GRANITSE TRETICHNOY I CHETVERTICHNOY SISTEMY NA GORNOM ALTAYE [ON THE TERTIARY-QUATERNARY BOUNDARY IN GORNYY ALTAY]: Tez. dokl. Mezhved. soveshch. po geol. chetvertichn. perioda, 1957.

8. Speranskiy, B.F., OSNOVNYYE MOMENT KAYNOZOYSKOY ISTORII YUGOVOSTOCHNOGO ALTAYA [MAIN EVENTS IN THE CENOZOIC HISTORY OF THE SOUTHEASTERN ALTAY]: Vestn. Zap.-Sib. geol/tresta, no. 5, 1937.

9. Shorygina, L.D., KAYNOZOYSKIYE LTLOZHENIYA ZAPADNOY TUVY [CENOZOIC DEPOSITS OF WESTERN TUVA]: Tr. Geol. in-ta Akademiya Nauk SSSR, ser. geol., no. 5, 1958.

10. Shchukina, Ye.N., ZAKONOMERNOSTI RAZMESHCHENIYA CHETVERTICHNYKH OTLOZHENIY I IKH STRATIGRAFIYA NA TERRITORII ALTAYA [PATTERN OF DISTRIBUTION AND STRATIGRAPHY OF QUATERNARY DEPOSITS ON THE ALTAY TERRITORY]: Tr. Geol. in-ta Akademiya Nauk SSSR, vyp. 26, 1958.

11. Yakovlev, T.A., O PROISKHOZHDENII TELETSKOGO OZERA [THE ORIGIN OF LAKE TELETSK]: Izv. Gorn.-geol. ob"yedin., t. 52, vyp. 6, 1916.

12. Yakovlev, S.A., K VOPROSU O PROISKHOZHDENII TELETSKOGO OZERA [THE PROBLEM OF ORIGIN OF LAKE TELETSK]: Byul. Mosk. o-va ispyt. prirody, otd. geol., t. no. 4-5, 1939.

13. Yakovleva, S.V., K IZUCHENIYE LEDNIKOVYKH VALUNOV NA RUSSKOY RAVNINE. MATERIALY PO CHETVERTICHNOY GEOLOGII I GEOMORFOLOGII SSSR [GLACIAL BOULDERS ON THE RUSSIAN PLAIN. MATERIALS ON QUATERNARY GEOLOGY AND GEOMORPHOLOGY]: Gosgeolizdat., 1941.

14. __________, ISSLEDOVANIYE LEDNIKOVYKH VALUNOV. METODICHESKOYE RUKOVODSTVO PO IZUCHENIYU I GEOLOGICHESKOY S"YEMKE CHETVERTICHNYKH OTLOZHENIY, CH. 2 [STUDY OF GLACIAL BOULDERS. METHODS OF STUDY AND GEOLOGICAL MAPPING OF QUATERNARY DEPOSITS, PT. 2]: Gosgeolizdat, 1955.

15. __________, OB ISSLEDOVANII LEDNIKOVYKH VALUNOV [INVESTIGATION OF GLACIAL BOULDERS]: Gosgeolizdat, 1941.

16. Carruthers, R.G., ON NORTHERN GLACIAL DRIFTS: SOME PECULIARITIES

AND THEIR SIGNIFICANCE: Quart. J. Geol. Soc. London, vol. 95, no. 379, 1939.

17. Glen, J.W., J.J. Donner and R.G. West, ON THE MECHANISM BY WHICH STONES IN TILL BECOME ORIENTED: Amer. J. Sci., vol. 255, no. 3, 1957.

18. Holmes, C.D., TILL FABRIC: Bull. Amer. Geol. Sev. vol. 52, no. 9, 1941.

BIBLIOGRAPHY

ARTICLES PUBLISHED IN PERIODICALS AND NON-PERIODICAL GEOLOGICAL LITERATURE (IN THE LIBRARY OF THE DEPARTMENT OF GEOLOGICAL-GEOGRAPHIC SCIENCES OF THE ACADEMY OF SCIENCES OF THE U.S.S.R., APRIL 1959)

A. Articles in Periodicals

GEOLOGY

1. Azizbekov, Sh.A., M.B. Zeynalov and T.G. Gadzhiyev, FATSII I MOSHCHNOSTI DEVONSKIKH OTLOZHENIY NAKHICHEVANSKOY SKLADCHATOY OBLASTI [FACIES AND THICKNESS OF DEVONIAN DEPOSITS OF THE NAKHICHEVAN FOLDED REGION]: Doklady, Akademiya Nauk Azerb.S.S.R., t. 15, no. 3.

2. Bezborodov, R.S., I.A. Konukhov and G.Ya. Krymgol'ts, NOVYE DANNYE PO STRATIGRAFII VERKHNELEYASOVYKH I SREDNEYURSKIKH OTLOZHENIY TSENTRAL'NOY CHASTI SEVERNOGO SKLONA KAVKAZA [NEW DATA ON THE UPPER LIASSIC AND MIDDLE JURASSIC DEPOSITS OF THE CENTRAL PART OF NORTHERN SLOPE OF THE CAUCASUS]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

3. Vasil'yev, V.G., G.L. Grishin and N.B. Mokashevich, STRATIGRAFIYA MESOZOYSKIKH OTLOZHENIY VOSTOCHNOY CHASTI MONGOLII [STRATIGRAPHY OF MESOZOIC DEPOSITS OF EASTERN MONGOLIA]: Sov. geol., no. 2.

4. Verte, A.I., O TEKTONICHESKOY PRIRODE ODNOY MALOY KUPOLOVIDNOY STRUKTURY V RAYONE G. TALLINA [ON THE TECTONIC ORIGIN OF A SMALL DOMICAL STRUCTURE NEAR TALLIN]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

5. Gorskiy, I.I., MEZHDUNARODNYY KONGRESS PO UGLEPETROGRAFII I MEZHDUNARODNYY KONGRESS PO STRATIGRAFII I GEOLOGII KARBONA [INTERNATIONAL CONGRESS ON COAL PETROGRAPHY, STRATIGRAPHY AND CARBONIFEROUS GEOLOGY]: (Heerlen, Holland), Sov. Geol., no. 3.

6. Grossgeim, V.A., PALEOTSEN I EOTSEN FLISHEVOY ZONY YUZHNOGO SKLONA SEVERO-ZAPADNOGO KAVKAZA [PALEOCENE AND EOCENE OF THE FLYSCH ZONE ON THE SOUTHERN SLOPE OF NORTHWESTERN CAUCASUS]: Izv. vyssh. uchebn. zaved., ser. geol. i pazvedki, no. 1.

7. Gumenskiy, B.M., GEOLOGIYA V LENINGRADSKOM INSTITUTE INZHENEROV ZHELEZNODOROZHNOGO TRANSPORTA IM. AKAD. V.N. OBRAZTSOVA [GEOLOGY IN THE V.N. OBRAZTSOV INSTITUTE OF ENGINEERS OF RAILWAY TRANSPORT]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedki, no. 1.

8. Dzvelaya, M.F., GEOLOGICHESKOYE STROENIYE KOLKHIDSKOY NIZMENNOSTI [GEOLOGICAL STRUCTURE OF THE COLCHIS PLAIN]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

9. Zhukova, Ye.A., K STRATIGRAFII OTLOZHENIY NIZHNEMELOVOGO VOZRASTA RAYONOV AKRABAT, TOYCHISAY PO FAUNE FORAMINIFER [STRATIGRAPHY OF LOWER CRETACEOUS DEPOSITS OF THE AKRABAT AND TOYCHISAY REGIONS ON THE BASIS OF FORAMINIFERAL FAUNA]: Doklady, Akademiya Nauk Ux.S.S.R., no. 3.

10. Ivanovskiy, A.B., K VOPROSU O STRATIGRAFICHESKOM POLOZHENII NIZHNELUDLOVSKOGO POD"YARUSA V PREDELAKH ZAPADNOY CHASTI SIBIRSKOY PLATFORMY [ON THE STRATIGRAPHIC POSITION OF THE LOWER LUDLOWIAN SUBSTAGE IN THE WESTERN PART OF THE SIBERIAN PLATFORM]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

11. Kalugin, Kh.I., OSNOVNYYE DANNYYE PO STRATIGRAFII PERMSKIKH I MESOZOYSKIKH OTLOZHENIY ZAPADNOY CHASTI OBLASTI OKHOTSKOKOLYMSKOGO VODORAZDELA [BASIC DATA ON THE STRATIGRAPHY OF PERMIAN AND MESOZOIC DEPOSITS OF THE WESTERN PART OF THE OKHOTSK-KOLYMA WATERSHED]: Sov. geol., no. 2.

12. Kanayev, V.F., NOVYYE DANNYYE O REL'YEFE DNA TSENTRAL'NOY CHASTI KAROLINSKOY KOTLOVINY [NEW DATA ON THE BOTTOM RELIEF OF THE CENTRAL PART OF THE CAROLINES DEEP-SEA BASIN]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

13. Karpov, P.A., K VOPROSU O VOZRASTE PRIKASPIYSKOY VPADINY [ON THE AGE OF THE CASPIAN DEPRESSION]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

14. Kirikov, D.A. and Ye.A. Modzalevskaya, PALEOZOYSKIYE I DOPALEOZOYSKIYE OTLOZHENIYA BASSEYNA R. ZEI [PALEOZOIC AND PRE-PALEOZOIC DEPOSITS IN THE ZEYA RIVER BASIN]: Sov. geol., no. 3.

15. Kovalevskiy, O.P., O VOZRASTE SILURIYSKIKH KARBONATNYKH TOLSHCH TSENTRAL'NOGO KAZAKHSTANA [ON THE AGE OF THE SILURIAN CARBONATE ROCKS OF CENTRAL KAZAKHSTAN]: Sov. geol., no. 3.

16. Kulikov, M.V., STRATIGRAFICHESKAYA SKHEMA PERMSKIKH OTLOZHENIY ZABAYKAL'YA [PERMIAN STRATIGRAPHY OF TRANSBAIKALIA]: Doklady, Akademiya Yauk SSSR, t. 125, no. 5.

17. Letavin, A.I. and N.A. Krylov, O PEREKHODNOM KOMPLEKSE PREDKAVKAZ'YA [THE TRANSITIONAL COMPLEX OF CISCAUCASIA]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

18. Lobanova, V.V., ROL' PIROKLASTICHESKOGO MATERIALA V FORMIROVANII SOLYANOY TOLSHCHI PODNYATIYA ZAPADNYY AZGIR [ROLE OF PYROCLASTIC MATERIAL IN THE FORMATION OF THE SALT MASS OF THE ZAPADNYY AZGIR UPLIFT]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

19. Lyashenko, A.I. and S.I. Novozhilova, K VOPROSU O VOZRASTE I RASHCHLENENII SHUGOROVSKOY SVITY VERKHNEGO DEVONA VOLGO-URAL'SKOY OBLASTI [ON THE AGE AND SUBDIVISION OF THE UPPER DEVONIAN SHUGUROVO FORMATION OF THE VOLGA-URALS REGION]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

20. Malovitskiy, Ya.P. and Yu.A. Sudarikov, NEKOTORYYE CHERTY TEKTONIKI I GEOLOGICHESKOY ISTORII CHIRSKO-DONSKOGO MEZHDURECH'YA [CERTAIN FEATURES OF TECTONICS AND GEOLOGICAL HISTORY OF THE CHIR-DON INTERFLUVE]: Sov. geol., no. 3.

21. Mikhaylov, A.Ye. and I.B. Filippova, ORDOVIKSKIYE OTLOZHENIYA VERKHNE-ATASUYSKOGO RAYONA TSENTRAL'NOGO KAZAKHSTANA [ORDOVICIAN DEPOSITS OF THE VERKHNE-ATASUY REGION OF CENTRAL KAZAKHSTAN]: Sov. geol. no. 3.

22. Mustafayev, I.S., K PALEOGEOGRAFII BASSEYNA VERKA PRODUKTIVNOY TOLSHCHI [PALEOGEOGRAPHY OF THE BASIN IN THE PRODUKTIVNAYA TOLSHCHA TIME]: Izv. vyssh. uchebn. zaved., ser. neft' i gaz, no. 2.

23. Nagibina, M.S., SKHEMA TEKTONIKI SEVERNOY MAN'CHZHURII [TECTONIC OUTLINE OF NORTHERN MANCHURIA]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

24. Neprochnov, Yu.P., GLUBINNOYE STROYENIYE ZEMNOY KORY POD CHERNYM MOREM K YUGO-ZAPADU OT KRYMA PO SEYSMICHESKIM DANNYM [DEEP STRUCTURE OF THE CRUST UNDER THE BLACK SEA TO THE SOUTHWEST OF CRIMEA ACCORDING TO SEISMIC DATA]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

25. Nikonov, A.A., VOSSTANOVLENIYE NEOTEKTONIKI I PALEOGEOGRAFII POZDNELEDNIKOV'YA S POMOSHCH'YU EPERYROGENICHESKOGO SPEKTRA V MATERIKOVOI CHASTI KOL'SKOGO POLUOSTROVA [RECONSTRUCTION OF NEOTECTONICS AND PALEOGEOGRAPHY OF THE CONTINENTAL PART OF THE KOLA PENINSULA IN POSTGLACIAL TIME WITH THE AID OF THE SEQUENCE OF EPEIROGENIC MOVEMENTS]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

27. Obut, A.M., ZONAL'NOYE RASCHLENENIYE SILURA V SSSR PO GRAPTOLITAM [SUBDIVISION OF THE SILURIAN OF THE USSR INTO ZONES WITH THE AID OF GRAPTOLITES]: Sov. geol., no. 2.

28. Pashaly, N.V. and F.I. Vekilova, K LITOLOGII GLIN CHETVERTICHNYKH

OTLOZHENIY LENKORANSKOY OBLASTI [CLAY LITHOLOGY OF THE QUATERNARY DEPOSITS IN THE LENKORAN' DISTRICT]: Doklady, Akademiya Nauk Azerb. S. S. R., t. 15, no. 3.

29. Pervago, V. A., ZADACHI URAL'SKIKH GEOLOGOV V 1959 GODU [PROBLEMS FACING URALIAN GEOLOGISTS IN 1959]: Inform. byul. Ural'sk. geol. upr. i Soveta nauchn.-tekhn. gorn. o-va, no. 1 (13).

30. Petrenko, V. S., O FORMIROVANII POMORSKO-KUYAVSKOY ZONY PODNYATIY [FORMATION OF THE POMOR'YE-KUYAVY ZONE OF UPWARPS]: Sov. geol., no. 2.

31. Plyusnin, K. T., NOVYYE DANNYYE O GEOLOGICHESKOM STROYENII MAGNITOGORSKOGO PROGIBA [NEW DATA ON THE FORMATION OF MAGNITOGORSK DOWNWARP]: Inform. byul. Ural'sk. geol. upr. i Soveta Nauchn.-tekhn. gorn. o-va, no. 1 (13).

32. Rezanov, I. A., O RIFEYSKIKH OTLOZHENIYAKH OKHOTSKOGO MASSIVA [RIPHEAN DEPOSITS OF THE OKHOTSK MASSIF]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

33. Ronenson, B. M., OSNOVNYYE CHERTY GEOLOGICHESKOGO STROYENIYA SEVERNOY CHASTI VISHNEVYKH GOR [MAIN STRUCTURAL FEATURES OF THE NORTHERN PART OF THE VISHNEVYYE GORY]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedki, no. 1.

34. Svarichevskaya, Z. A., OBZOR OSNOVNYKH VOZZRENIY O RAZVITH REL'YEVA VOSTOCHNOGO KAZAKHSTANA [REVIEW OF THE MAIN VIEWS ON THE DEVELOPMENT OF RELIEF IN EASTERN KAZAKHSTAN]: Vestn LGU, no. 6, ser. geol. i geogr., vyp. 1.

35. Sigal, L. A., K ISPOL'ZOVANIYU DANNYKH ELEKTROMETRICHESKIKH ISSLEDOVANIY V SKVAZHINAKH DLYA IZUCHENIYA NEKOTORYKH VOPROSOV TEKTONIKI ZAPADNO-SIBIRSKOY NIZMENNOSTI [APPLICATION OF ELECTROMETRIC INVESTIGATIONS IN BOREHOLES TO THE STUDY OF CERTAIN TECTONIC PROBLEMS OF THE WEST SIBERIAN PLAIN]: Sov. geol., no. 3.

36. Sollogub, V. B., NEKOTORYE DANNYYE O BLOKOVOM STROYENII YUGA UKRAINSKOY SSR [CERTAIN DATA ON THE BLOCK STRUCTURE OF THE SOUTH OF THE UKRAINIAN SSR]: Dopovidi, Akademiya Nauk Ukr. S. S. R., no. 3.

37. Solov'yev, Yu. Ya., KOMISSIYA PO GEOLOGICHESKOY IZUCHENNOSTI SSSR [COMMITTEE ON THE EXISTING GEOLOGICAL KNOWLEDGE OF THE U. S. S. R.]: Sov. geol., no. 3.

38. Sultanov, A. D. and M. G. Agabekova, IZVERZHENIYE GRYAZEVOGO VULKANA BANKI MAKAROVA [ERUPTION OF MUD VOLCANO BANKA MAKAROVA]: Doklady, Akademiya Nauk Azerb. S. S. R., t. 15, no. 2.

39. Tikhvinskiy, I. N., K KHARAKTERISTIKE REL'YEFA PERMSKOY SUSHI YUGA TATARII I PRILEGAYUSHCHIKH RAYONOV [RELIEF FEATURES OF THE PERMIAN LAND OF THE SOUTH OF TATARIA AND OF ADJACENT REGIONS]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

40. Ustiyev, Ye. K., OKHOTSKIY TEKTONOMAGMATICHESKIY POYAS I NEKOTORYYE SVYAZANNYYE S NIM PROBLEMY [THE OKHOTSK TECTONOMAGMATIC BELT AND SOME OF THE PROBLEMS RELATED TO IT]: Sov. geol., no. 3.

41. Fominskiy, V. I., NOVYYE DANNYYE DLYA STRATIGRAFII ORDOVIKA GORNOGO ALTAYA [NEW DATA ON ORDOVICIAN STRATIGRAPHY OF GORNYY ALTAY]: Sov. geol. no. 2.

42. Chayko, G. I., A. N. Zakhar'yevich and Yu. S. Yemel'yanov, NEKOTORYYE REZUL'TATY GEOLOGOS"YEMOCHNYKH RABOT V MAGNITOGORSKOM RAYONE [CERTAIN RESULTS OF GEOLOGICAL MAPPING IN THE MAGNITOGORSK REGION]: Inform. byul. Ural'sk. geol. upr i soveta nauchn.-tekhn. gorn. o-va, no. 1 (13).

43. Charygin, M. M. and I. V. Bezborodova, K ISTORII GEOLOGICHESKOGO RAZVITIYA MEZHDURECH'YA PSEKHA-KUBAN NA SEVERNOM KAVKAZE V VERKHNEYURSKOE VREMYA [GEOLOGICAL HISTORY OF DEVELOPMENT OF THE PSHEKHA-KUBAN' INTERFLUVE IN NORTHERN CAUCASUS DURING UPPER JURASSIC TIME]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

44. Sheynmann, Yu. M., DREVNEYSHIYE STRUKTURY PLATFORM I IKH

ZNACHENIYE DLYA OBSHCHEY TEKTONIKI [THE OLDEST PLATFORM STRUCTURES AND THEIR SIGNIFICANCE TO GENERAL TECTONICS]: Sov. geol., no. 3.

45. Shishigin, S.I., O KHARAKTERE IZMENENIYA PORISTOSTI PESCHANO-ALEVRITOVYKH POROD SKIBOVOY ZONY KARPAT [THE CHARACTER OF VARIATION IN POROSITY OF THE SAND-SILT BEDS OF THE SKIBOV ZONE IN THE CARPATHIANS]: Izv. vyssh. uchebn. zaved., ser. neft' i gaz, no. 2.

46. Eventov, Ya.S., K VOPROSU O METODIKE OBSHCHEGO GEOLOGICHESKOGO IZUCHENIYA ZAKRYTYKH RAYONOV [ON THE METHOD OF INVESTIGATION OF CLOSURES]: Geol. nefti i gaza, no. 4.

47. Egamberdyyev, M., K USTANOVLENIYU AL'BSKIKH OTLOZHENIY V GORAKH AUMINZATAU [THE DISCOVERY OF ALBIAN DEPOSITS IN THE AUMINZATAU MOUNTAINS]: Doklady, Akademiya Nauk Uz.S.S.R., no. 3.

48. Edel'shteyn, A.Ya., K VOPROSU O TEKTONICHESKOM STROYENII PREDDOBRUDZHSKOY VPADINY [ON THE GEOLOGIC STRUCTURE OF THE DOBRUDZHA DEPRESSION]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedki, no. 1.

PALEONTOLOGY

49. Belokrys, L.S., OB ODNOY FORME OKREMENENIYA STVOROK ISKOPAYEMYKH RAKOVIN [A TYPE OF SILICIFICATION OF FOSSIL SHELLS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedki, no. 1.

50. Voinstvenskiy, M.A. and A.S. Umanskaya, PTITSY IZ SOVREMENNYKH ALLUVIAL'NYKH OTLOZHENIY NIZHNEGO DNEPRA [BIRDS FROM THE RECENT ALLUVIUM OF THE DNEPR]: Dopovidi, Akademiya Yauk Ukr.S.S.R., no. 3.

51. Gekker, R.F., O NAPRAVLENIYAKH I METODAKH PALEOKOLOGICHESKIKH ISSLEDOVANIY VODNYKH FAUN [TRENDS AND METHODS IN PALEOECOLOGICAL INVESTIGATIONS OF AQUATIC FAUNAS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedki, no. 1.

52. Didkovskiy, V.Ya., NOVYY VID FORAMINIFER MOLIOLINA PODOLICA SP. N. IZ VERKHNETORTONSKIKH OTLOZHENIY PODOLII [A NEW SPECIES OF FORAMINIFER MOLIOLINA PODOLICA SP.N. FROM UPPER TORTONIAN DEPOSITS OF PODOLIA]: Dopovidi, Akademiya Nauk Ukr.S.S.R., no. 3.

53. Ivanova, Ye.A. and I.I. Chudinova, NOVYYE DANNYYE PO FAUNE DEVONA KUZNETSKOGO BASSEYNA [NEW DATA ON DEVONIAN FAUNA OF THE KUZNETSK BASIN]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

54. Ivanovskiy, A.B., K VOPROSU O SISTEMATICHESKOM POLOZHENII ORDOVIKOVSKIKH I SILURIYSKIKH ZAFRENTOIDNYKH KORALLOV [ON THE POSITION OF ZAPHRENTOID CORALS IN SYSTEMATICS]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

55. Korde, K.B., PROBLEMATICHESKIYE OSTATKI IZ KEMBRIYSKIKH OTLOZHENIY YUGO-VOSTOKA SIBIRSKOY PLATFORMY [PROBLEMATICAL FOSSILS FROM CAMBRAIN DEPOSITS OF THE SOUTHEASTERN PART OF THE SIBERIAN PLATFORM]: Doklady, Akademiya Nauk SSSR, 5. 125, no. 3.

56. Maslov, V.P., STROMATOLITY I FATSII [STROMATOLITES AND FACIES]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

57. Miklukho-Maklay, A.D., O STRATIGRAFICHESKOM ZNACHENII, SISTEMATIKE I FILOGENII SHTAFELOOBRAZNYKH FORAMINIFER [STRATIGRAPHIC SIGNIFICANCE, SYSTEMATICS AND PHYLOGENY OF STAFELLA-LIKE FORAMINIFERA]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

58. Miklukho-Maklay, A.D., SISTEMATIKA I FILOGENIYA FUZULINID (ROD TRITICITES I BLIZKIYE K NEMU RODY) [SYSTEMATICS AND PHYLOGENY OF FUSULINIDS (TRITICITES AND RELATED GENERA]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

59. Samsonov, S.K., NESKOL'KO SLOV O NOVO-KASPIYSKOY FORE ZAPADNOY TURKMENII [A FEW WORDS ABOUT NEW-CASPIAN FLORA OF WESTERN TURKMENIA]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

PETROGRAPHY, MINERALOGY, CRYSTALLOGRAPHY, GEOCHEMISTRY

60. Abramovich, Ye.L. AUTIGENYY MAGNEZIAL'NYY GIDROKHLORIT V KARBONATNYKH PORODAKH KALKAN-ATA

[AUTHIGENIC MAGNESIAN HYDROCHLORITE IN CARBONATE ROCKS OF KALKAN-ATA]: Doklady, Akademiya Nauk Uz.S.S.R., no. 3.

61. Anikin, I.N., NEKOTORYYE USLOVIYA GIDROTERMAL'NOGO SINTEZA KRISTALLOV SHEELITA [CERTAIN CONDITIONS FOR HYDROTHERMAL SYNTHESIS OF SCHEELITE CRYSTALS]: Zap. Veses. min. o-va, ch. 88, vyp. 2.

62. Ankinovich, Ye.A., NOVYYE VANADIEVYYE MINERALY — SATPAYEVIT I AL'VANIT [NEW VANADIUM MINERALS — STAPAYEVITE AND ALVANITE]: Zap. Vses. min. o-va ch. 88, vyp. 2.

63. Bazhenov, I.K., Yu.V. Indukayev, and A.V. Yakhno, SAMORODNOYE ZHELEZO V GABBRO-DOLERITAKH R. KUREYKI (KRASNOYARSKIY KRAY) [NATIVE IRON IN DIABASE OF THE KUREYKA RIVER (KRASNOYARSK DISTRICT)]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

64. Balasanyan, S.I., SREDNIYE SOSTAVY MAGMATICHESKIKH POROD ARMENII [AVERAGE COMPOSITIONS OF ARMENIAN IGNEOUS ROCKS]: Geokhimiya, no. 3.

65. Barabanov, V.F., FLYUORIT IZ BUKUKINSKOGO VOL'FRAMITOVOGO MESTOROZHDENIYA (VOSTOCHNOYE ZABAYKAL'YE) [FLUORITE FROM WOLFRAMITE DEPOSITS OF BUKUKIN (EASTERN TRANSBAIKALIYA)]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

66. Belov, N.V. and V.I. Simonov, OB IZOMORFYNKH SOOTNOSHENIYAKH MEZHDU TSIRKONOM I TITANOM [ON ZIRCONIUM-TITAMIUM DIADOCHY]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

67. Belov, N.V., PO POVODU RABOTY A.A. BEUSA "O POLOZHENII SHCHELOCHNYKH METALLOV V STRUKTURE BERILLA" (CONCERNING A.A. BEUS' WORK: "THE POSITION OF ALKALI METALS IN THE BERYL STRUCTURE:]: Geokhimiya no. 4.

68. Betekhtin, A.G., KRITICHESKIYE ZAMECHANIYA PO KNIGAM: 1) R.V. GETSEVOY, K.T. SAVEL'YEVOY - "RUKOVODSTVO PO OPREDELENIYU URANOVYKH MINERALOV" AND 2) M.B. SOBOLEVOY. I.A. PUDOVKINOY - "MINERALY URANA" (SPRAVOCHNIK) [CRITICAL NOTES ON 1) "GUIDE TO THE DETERMINATION OF URANIUM MINERALS" BY R.V. GETSEVA AND K.T. SAVEL'YEVA AND 2) "URANIUM MINERALS" (HANDBOOK) BY M.V. SOBOLEVA AND I.A. PUDOVKINA]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

69. Beus, A.A., O POLOZHENII SHCHELOCHNYKH METALLOV V STRUKTURE BERILLA [ON THE POSITION OF THE ALKALI METALS IN BERYL STRUCTURE]: Geokhimiya, no. 3.

70. Bobriyevich, A.P., K METAMORFIZMU KSENOLITOV V KIMBERLITAKH VOSTOCHNOY SIBIRI [METAMORPHISM OF XENOLITHS IN THE KIMBERLITES OF EASTERN SIBERIA]: Zap/ Vses. min. o-va, ch. 88, vyp. 2.

71. Borneman-Starynkevich, I.D., KHIMICHESKIYE FORMULY MINERALOV [CHEMICAL FORMULAS OF MINERALS]: Zap/ Vses. min. o-va, ch. 88, vyp. 2.

72. Brodin, B.V., MINERALY OLOVA I IKH PARAGENEZIS V RUDAKH MESTOROZHDENIY KURGANSKOGO UZLA TALASSKOGO ALATAU [TIN MINERALS AND THEIR PARAGENESIS IN THE ORES OF THE DEPOSITS IN THE KURGANSKIY KNOT OF TALASSKIY ALATAU]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

73. Vasilevskaya, A.G., DVOYNYYE SOYEDINENIYA IZ SUL'FATOV KAL'TSIYA I NATRIYA I IKH ROL' V FORMIROVANII PRIRODNOGO TENARDITA [DOUBLE SALTS OF CALCIUM AND SODIUM AND THEIR ROLE IN THE FORMATION OF NATURAL THENARDITE]: Izv. Sib. otd. Akademiya Nauk SSSR, no. 1.

74. Vedernikova, G.A., DIFFERENTSIROVANNYY TRAPPOVYY MASSIV PADUNSKIKH POROGOV NA R. ANGARE [A DIFFERENTIATED DIABASE MASSIF OF THE PADUNSKIYE RAPIDS ON THE ANGARA RIVER]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

75. Vinogradov, A.P., V.M. Kutyurin and I.K. Zadorozhnyy, FRAKTSIONIROVANIYE IZOTOPOV ATMOSFERNOGO KISLORODA [FRACTIONATION OF ISOTOPES IN ATMOSPHERIC OXYGEN]: Geokhimiya, no. 3.

76. Vorob'yev, G.G. and M.A. Rotko, RIBEKIT IZ MONGOLII [RIEBECKITE FROM MONGOLIA]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

77. Gazizova, K.S. and M.P. Rusakov, O FIBROFERRITE IZ KOUNRADSKOGO MEDNOGO MESTOROZHDENIYA [FIBROFERRITE FROM THE KOUNRAD COPPER DEPOSIT]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

78. Dunayev, V.A., O RASPROSTRANENII BORA V NEKOTORYKH GORNYKH POROD URALA [THE DISTRIBUTION OF BORON IN SOME ROCKS OF THE URALS]: Geokhimiya, no. 3.

79. Zkhus, I.D. and G.P. Vagina, GLINISTYYE MINERALY MAYKOPSKOY SVITY RAYONA OZEK-SUAT [CLAY MINERALS OF THE MAIKOP FORMATION IN THE OZEK-SUAT REGION]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

80. Ivanov, V.V. and Yu.A. Pyatenko, O TAK NAZYVAYEMOM KESTERITE [ABOUT THE SO-CALLED CUSTERITE]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

81. Ivanov, V.V., L.F. Borisenko and N.V. Lizunov, SKANDIY V MINERALAKH QVARTSEVYKH ZHIL I GREYZENOV ODNOY IZ INTRUZIY KHR. POLOUSNOGO [SCANDIUM IN MINERALS OF QUARTZ VEINS AND GREISEN IN ONE OF THE INTRUSIVES OF THE POLOUSNYY RANGE]: Doklady, Akademiya Nauk SSSR, t. 125, no. 3.

82. Ignatchenko, N.A., O SOSTAVE I METAMORFIZME UGLEY YUZHNOY CHASTI LENSKOGO UGOL'NOGO BASSEYNA [COMPOSITION AND METAMORPHISM OF THE SOUTHERN PART OF THE LENA COAL BASIN]: Sov. geol., no. 3.

83. Il'inskiy, G.A., O PROTSESSAKH IZMENENIYA KHLORITA V PALEOZOYSKIKH METAMORFIZOVANNYKH KONGLOMERATAKH ZAPADNOGO SKLONA SEVERNOGO URALA [THE PROCESSES OF ALTERATION OF CHLORITE IN THE METAMORPHOSED CONGLOMERATES OF THE WESTERN SLOPE OF NORTHERN URALS]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

84. Kogan, V.D., K GENEZISU SAMORODNOY SERY [ON THE GENESIS OF NATIVE SULFUR]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

85. Kornilov, N.A., OB ANOMAL'NYKH OPTICHESKIKH SVOYSTVAKH NEKOTORYKH ASBESTOVIDNYKH GIDROSILIKATOV [ANOMALOUS OPTICAL PROPERTIES OF SOME ASBESTIFORM HYDROUS SILICATES]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

86. Krylov, A.Ya. and L.Ya. Atrashenok, O FORMAKH NAKHOZHDENIYA URANA V GRANITAKH [ON THE FORM OF OCCURRENCE OF URANIUM IN GRANITES]: Geokhimiya, no. 3.

87. Kuznetsov, Ye.A., O SISPERSII DVUPRELOMLENIYA [DISPERSION OF THE REFRACTIVE INDICES]: Izv. vysh. uchebn. zaved., ser. geol. i razvedki, no. 1.

88. Kuman, V.Ye., O NEKOTORYKH OSOBENNOSTYAKH NATROVOGO METASOMATOZA V KRIVOROZHSKOM BASSEYNE [CERTAIN CHARACTERISTICS OF SODA METASOMATISM IN THE KRIVOY ROG BASIN]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

89. Lebedev-Zinov'yev, A.A., POLEVYE SHPATY OLIGOKLAZOVYKH GRANIT-PORFIROV GORY BYK NA SEVERNOM KAVKAZE [FELDSPARS OF THE OLIGOCLASE GRANITE PORPHYRIES FROM MT. BYK, NORTHERN CAUCASUS]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

90. Lemmleyn, G.G., KLASSIFIKATSIYA ZHIDKIKH VKLYUCHENIY V MINERALAKH [CLASSIFICATION OF LIQUID INCLUSIONS IN MINERALS]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

91. Malinin, S.D., SISTEMS H_2O-CO_2 PRI VYSOKIKH TEMPERATURAKH I DAVLENIYAKH [THE SYSTEM H_2O-CO_2 AT HIGH TEMPERATURES AND PRESSURES]: Geokhimiya, no. 3.

92. Pavlova, I.G., O SFEROLITOVYKH AGREGATAKH TOPAZA [SPHERULITIC AGGREGATES OF TOPAZ]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

93. Pertsev, N.N. and I.B. Nikitina, NOVYYE DANNYYE O SEREBENDITE [NEW DATA ON SERENDIBITE]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

94. Plyushchev, V.Ye., VYSOKOTEMPERATURNYY SINTEZ POLLUTSITA [HIGH TEMPERATURE SYNTHESIS OF POLLUCITE]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

95. Pyatkov, K.K. and A.K. Bukharin, OSADOCHNYYE DAYKI V TSENTRAL'NYKH KYZYLKUMAKH [SEDIMENTARY DIKES IN CENTRAL KYZYLKUM]: Sov. geol., no. 3.

96. Ronov, A.B. and A.I. Yermishkina, RASPREDELENIYE MARGANTSA V OSADOCHNYKH PORODAKH [DISTRIBUTION OF MANGANESE IN SEDIMENTARY ROCKS]: Geokhimiya, no. 3.

97. Sayanov, V.S., K MINERALOGII GLINISTYKH MINERALOV MIOTSENOVYKH IZVESTNYAKOV SEVERO-ZAPADNOGO PRICHERNOMOR'YA [ON THE MINERALOGY OF CLAY MINERALS IN THE

MIOCENE LIMESTONES OF THE NORTHWESTERN PART OF THE BLACK SEA REGION]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

98. Sviridov, V.V., NOVYYE DANNYYE O DIABAZAKH SEVERO-ZAPADNOGO KAVKAZA [NEW DATA ON THE DIABASES OF THE NORTHWESTERN CAUCASUS]: Izv. vysh. uchebn. zaved. m ser. geol. i razvedki, no. 1.

99. Slepov, Yu.S. OSOBENNOSTI RASPROSTRANENIYA NEKOTORYKH REDKIKH ELEMENTOV V METAMORFICHESKIKH PORODAKH, GRANITAKH I REDKOMETAL'NYKH PEGMATITAKH SAYAN [PECULIARITIES OF DISTRIBUTION OF CERTAIN RARE ELEMENTS IN METAMORPHIC ROCKS, GRANITES AND RARE METAL PEGMATITES OF THE SAYAN RANGE]: Geokhimiya, no. 3.

00. Sobolev, N.D., KOLICHESTVENNO-MINERAL'NYY SOSTAV GRANITOIDOV [QUANTITATIVE MINERALOGY OF GRANITOIDS]: Sov. geol., no. 3.

01. Sokolov, D.S., RETSENZIYA NA KNIGU O.A. SAMOYLOVA "STRUKTURA VODNYKH RASTVOROV ELEKTROLITOV I GIDRATSIYA IONOV." AN SSSR, 1957 [REVIEW OF O.A. SAMOYLOV'S BOOK: "STRUCTURE OF ELECTROLYTES AND HYDRATION OF IONS." ACAD. SCI. ED., 1957]: Izv. vysh. uchebn. zaved., ser. geol. i razvedki, no. 1.

02. Sokolov, Yu.M., NEKOTORYYE VOPROSY RASPREDELENIYA SLYUD I DRUGIKH MINERALOV V PEGMATITOVYKH ZHILAKH CHUYSKOGO MESTOROZHDENIYA MUSKOVITA (MAMSKO-CHUYSKIY SLYUDONOSNYY RAYON) [CERTAIN QUESTIONS OF DISTRIBUTION OF MICAS AND OTHER MINERALS IN THE PEGMATITES OF THE CHUYSK MUSCOVITE DEPOSIT (MAMSK-CHUYSK MICA REGION)]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

03. Stashkov, N.V. and A.I. Zelyanskaya, POLYAROGRAFICHESKOYE OPREDELENIYE GERMANIYA [POLAROGRAPHIC DETERMINATION OF GERMANIUM]: Izv. Sib. otd. Akademiya Nauk SSSR, no. 1.

04. Stishov, S.M., PO POVODU STAT'I V.M. VINOKUROVA "O SINEM GALITE IZ SOLIKAMSKIKH MESTOROZHDENIY" [COMMENT ON V.M. VINOKUROV'S PAPER "BLUE HALITE FROM THE SOLIKAMSK DEPOSITS"]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

05. Sudovnikov, N.G., UL'TRAMETAMORFIZM I GRANITOOBRAZOVANIYE [ULTRAMETAMORPHISM AND FORMATION OF GRANITE]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

106. Fedyuk, Ferri, O DIAGRAMAKH DLYA OPREDELENIYA PLAGIOKLASOV NA FEDOROVSKOM STOLIKE [DIAGRAMS FOR PLAGIOCLASE DETERMINATION ON THE UNIVERSAL STAGE]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

107. Frank-Kamenetskiy, V.A., O "RENTGENOMETRICHESKOM OPREDELITELE MINERALOV" V.I. MIKHEYEVA [ON THE TABLES FOR MINERAL DETERMINATION BY X-RAY DIFFRACTION" BY V.I. MIKHEYEV]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

108. Khalifa-zade, Ch.M. and S.M. Abbasova, SHAMOZITOVYYE GLINY IZ OTLOZHENIY KIMERIDTA YUGO-VOSTOCHNOGO KAVKAZA [CHAMOSITE CLAYS FROM THE KIMMERIDGIAN OF SOUTHEASTERN CAUCASUS]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

109. Chepikov, K.R., Ye.P. Yermolova and N.A. Orlova, EPIGENNYYE MINERALY KAK POKAZATELI VREMENI PRIKHODA NEFTI V PESCHANYYE PROMYSHLENNYYE KOLLEKTORY [EPIGENETIC MINERALS AS INDICATORS OF THE TIME OF ARRIVAL OF PETROLEUM IN THE PRODUCTIVE SAND RESERVOIRS]: Doklady, Akademiya Nauk SSSR, t. 125, no. 5.

110. Shamray, I.A., PETROGRAFICHESKIYE OSOBENNOSTI I USLOVIYA FORMIROVANIYA OSADKOV SEVERNOY CHASTI MAYKOPSKOGO BASSEYNA [PETROGRAPHIC CHARACTERISTICS AND CONDITIONS OF FORMATION OF THE SEDIMENTS IN THE NORTHERN PART OF THE MAYKOP BASIN]: Izv. vysh. uchehn. zaved., ser. neft' i gaz, no. 2.

MINERAL RESOURCES,
METHODS OF PROSPECTING AND LOCATION

111. Aleksin, A.G., O PRINTSIPIAL'NOY SKHEME METODIKI POISKOV I RAZVEDKI SKOPLENIY NEFTI I GASA [THE PRINCIPAL METHODS OF SEARCH AND EXPLORATION FOR GAS AND OIL ACCUMULATIONS]: Geol. nefti i gaza, no. 4.

112. Aleskovskiy, V.B., A.A. Mokhov and V.N. Spirov, ISPOL'ZOVANIYE BIOGEOKHEMICHESKOGO METODA POISKOV NIKELYA NA KOL'SKOM POLUOSTROVE

[BIOGEOCHEMICAL METHOD OF PROSPECTING FOR NICKEL ON KOLA PENINSULA]: Geokhimiya, no. 3.

113. Bogatsiy, V.V., OSOBENNOSTI RAZMESHCHENIYA I PERSPEKTIVY METASOMATICHESKOGO MAGNETITOVOGO ORUDNENIYA SEVERNYKH RAYONOV ZAPADNOGO SAYANA [CHARACTERISTICS OF DISTRIBUTION AND THE POSSIBILITIES OF THE METASOMATIC MAGNETITE MINERALIZATION IN THE NORTHERN REGIONS OF WESTERN SAYAN]: Sov. geol., no. 3.

114. Bondar', V.P., O MESTOROZHDENII TSELESTINA, SVYAZANNOM S GIDROTERMAL'NOY DEYATEL'NOST'YU TRAPPOV NA TERRITORII SIBIRSKOY PLATFORMY [A CELESTITE DEPOSIT RELATED TO BASALTIC HYDROTHERMAL ACTIVITY ON THE TERRITORY OF THE SIBERIAN PLATFORM]: Zap. Vses. min. o-va, ch. 88, vyp. 2.

115. Gavasheli, A.V., KOBAL'T I NIKEL' V MARGANTSEVYKH RUDAKH CHIATURO-SACHKHERSKOGO BASSEYNA [COBALT AND NICKEL IN THE MANGANESE ORES OF THE CHIATURI-SACHKHERE BASIN]: Sov. geol., no. 2.

116. Glushko, V.V. and V.T. Skylar, NEFT' VO VNESHNEY ZONE PREDKARPATSKOGO PROGIBA [PETROLEUM IN THE OUTER ZONE OF THE EAST CARPATHIAN DOWNWARP]: Geol. nefti i gaza, no. 4.

117. Dzhafarov, Ch.D., PROTSESSY RUDOOBRAZOVANIYA NA UCHASTKE SUKHARNYY LOG (SALAIR) [THE PROCESSES OF ORE DEPOSITION IN THE SUKHARNYY LOG AREA (SALAIR)]: Doklady, Akademiya Nauk Axerb.S.S.R., t. 15, no. 3.

118. Konoplyantsev, M.A., MOLIBDENOVYYE MESTOROZHDENIYA TSENTRAL'NOGO KAZAKHSTANA [MOLYBDENUM DEPOSITS OF CENTRAL KAZAKHSTAN]: Sov. geol., no. 2.

119. Kotel'nikov, V.M., PERSPEKTIVY NEFTEGAZONOSNOSTI DEVONSKIKH OTLOZHENIY V TERSINSKOY VPADINE I USLOVIYA FORMIROVANIYA NEFTYANYKH ZALEZHEY NA KLENOVSKOM PODNYATII [THE POSSIBILITY OF OIL AND GAS OCCURRENCE IN THE DEVONIAN ROCKS OF THE TERSK BASIN AND THE CONDITIONS OF FORMATION OF OIL POOLS ON THE KLENOVSKIY UPWARP]: Geol. nefti i gaza, no. 4.

120. Krasnikov, V.I., SOVESHCHANIYE PO POISKAM SLEPYKH RUDNYKH TEL [CONFERENCE ON THE SEARCH FOR CONCEALED ORE BODIES]: Geokhimiya, no. 3.

121. Levitskiy, O.D. and V.I. Smirnov, ZNACHENIYE PERVICHNOY ZONAL'NOSTI DLYA POISKOV RUDNYKH TEL GIDROTERMAL'NOGO PROISKHOZHDENIYA NE VYKHODYASHCHIKH NA POVERLHNOST' [THE SIGNIFICANCE OF PRIMARY ZONING IN PROSPECTING FOR CONCEALED HYDROTHERMAL ORE BODIES]: Sov. geol., no. 2.

122. Leont'yev, V.M., O NEKOTORYKH OSOBENNOSTYAKH INTERPRETATSII DIAGRAMM MIKROZONDOV V KARBONATNYKH RAZREZAKH [CERTAIN FEATURES OF INTERPRETATION OF MICROSONDE DIAGRAMS FROM CARBONATE SECTIONS]: Geol. nefti i gaza, no. 4.

123. Lider, V.A., STRUKTURNO-GENETICHESKIYE ZAKONOMERNOSTI YURSKOGO UGLENAKOPLENIYA NA VOSTOCHNOM SKLONE SEVERNOGO I POLYARNOGO URALA [STRUCTURAL AND GENETIC CHARACTERISTICS OF JURASSIC COALS ON THE EASTERN SLOPE OF NORTHERN AND POLAR URALS]: Inform. byul. Ural'sk. geol. upr. i Soveta nauch.-tekn. gorn. o-va, no. 1 (13).

124. Lisyakevich, S., ZHIL'NYYE RUDNYYE PROYAVLENIYA V MEDNOM MESTOROZHDENII TIPA MANSFELDA V SEVERO-SUDETSKOY MUL'DE [ORE VEINS IN THE COPPER DEPOSIT OF THE MANSFELD TYPE IN THE NORTH SUDETEN BASIN]: Izv. vysh. uchebn. zaved., ser. geol. i razvedki, no. 1.

125. Markovskiy, N.I., UGLENOSNOST' I PROGNOZ NEFTEGAZONOSNOSTI [PRESENCE OF COAL AND PETROLEUM AND GAS PROGNOSIS]: Priroda, no. 4.

126. Mekhtiyev, Sh.F. and S.A. Aliyev, O FAKTORAKH VLIYAYUSHCHIKH NA VELICHINU GEOTERMICHESKOY STUPENI NEFTYANYKH MESTOROZHDENIY AZERBAYDZHANA [THE FACTORS AFFECTING THE GEOTHERMAL GRADIENT IN THE PETROLEUM DEPOSITS OF AZERBAIJAN]: Doklady, Akademiya Nauk, Azerb.S.S.R., t. 15, no. 2.

127. Mironov, S.I., DEYATEL'NOST' I.M. GUBKINA – OBRAZETS SVYAZI NAUCHNOGO TVORCHESTVA S PRAKTIKOY [THE WORK OF I.M. GUBKIN – AN EXAMPLE OF UNION BETWEEN SCIENTIFIC CREATION AND PRACTICE]:

Geol. Nefti i gaza, no. 4.

8. Mironov, Yu.K., PERSPEKTIVY NEFTENOSNOSTI RAYONOV SREDNEGO TECHENIYA R. OBI ZAPADNO-SIBIRSKOY NIZMENNOSTI [THE PETROLEUM POTENTIALITIES OF THE REGIONS ON THE MIDDLE COURSE OF THE OB RIVER ON THE WEST-SIBERIAN PLAIN]: Sov. geol., no. 2.

9. Mirchink, M.F., ROL' UCHENIYA I.M. GIBKINA V RAZVITII NEFTYANOY GEOLOGII I NEFTE-GAZODOBYVAYUSHCHEY PROMYSHLENNOSTI SSSR [THE ROLE OF I.M. GIBKIN'S TEACHING IN THE DEVELOPMENT OF PETROLEUM GEOLOGY AND THE GAS AND PETROLEUM INDUSTRY IN THE U.S.S.R.]: Geol. nefti i gaza, no. 4.

0. RESHENIYE PERVOGO VSESOYUZNOGO SOVESHCHANIYA PO RAZRABOTKE NAUCHNYKH OSNOV POISKOV SKRYTOGO ORUDNENIYA [REPORT OF THE FIRST ALL-UNION CONFERENCE ON THE DEVELOPMENT OF THE SCIENTIFIC BASIS OF PROSPECTING FOR CONCEALED ORE DEPOSITS]: Sov. geol., no. 2.

1. Rimskaya-Korsakova, O.M., V.V. Sakhonenok and N.A. Kulik, LYANGARSKOYE MOLIBDENO-VOL'FRAMOVOYE MESTOROZHDENIYA [THE LYANGAR MOLYBDENUM-TUNGSTEN DEPOSIT]: Vest. LGU, no. 6, ser. geol. i geogr., vyp. 1.

2. Satpayev, K., RETSENZIYA NA KNIGU: "TEKTONICHESKOYE STROYENIYE I ISTORIYA RAZVITIYA PRIKASPIYSKOY VPADINY I SMIZHNYKH OBLASTEY V SVYAZI S VOPROSAMI NEFTEGAZONOSNOSTI" [REVIEW OF THE BOOK: "STRUCTURE AND HISTORY OF DEVELOPMENT OF THE CASPIAN DEPRESSION AND ADJACENT REGIONS IN CONNECTION WITH OIL AND GAS POTENTIALITIES" GOSTOPTEKHIZDAT, 1958]: Geol. nefti i gaza, no. 4.

3. Sergeyev, O.P., BAKAL'SKOYE MESTOROZHDENIYE ZHELEZNYKH RUD, KAK OSNOVNAYA RUDNAYA BAZA CHELYABINSKOGO METALLURGICHESKOGO ZAVODA [THE BAKAL IRON DEPOSIT AS THE MAIN SOURCE OF ORE FOR THE CHELYABINSK METALLURGICAL PLANT]: Inform. byull. Ural'sk. geol. upr. i Soveta nauchn.-tekhn. gorn. o-va, no. 1 (13).

4. N.M. SINITSIN NEKROLOG [N.M. SINITSIN — OBITUARY]: Sov. geol., no. 2.

135. Sinitsin, N.M., O VOZRASTE RTUTNOSUR'MYANOGO ORUDENIYA ZAPADNOGO TYAN'-SHANYA [THE AGE OF THE MERCURY-ANTIMONY MINERALIZATION IN WESTERN TIEN SHAN]: Sov. Geol., no. 2.

136. Smirnov, V.I., EVOLYUTSIYA ENDOGENNOGO RUDOOBRAZOVANIYA [EVOLUTION OF ENDOGENIC ORE DEPOSITS]: Priroda, no. 4.

137. Solovov, A.P. and V.Z. Fursov, POISKI NE VYKHODYASHCHIKH NA POVERKHNOST' RUDNYKH TEL MESTOROZHDENIYA ACHISAY [PROSPECTING FOR CONCEALED ORE BODIES AT ACHISAY]: Sov. geol., no. 3.

138. Solov'yev, Yu.S., K.K. Koloyev and N.S. Krutsko, OSOBENNOSTI GEOLOGICHESKOGO STROYENIYA I PERSPEKTIVY GLUBOKIKH GORIZONTOV BAZHENOVSKOGO MESTOROZHDENIYA KHRIZOTIL-ASBESTA [PECULIARITIES OF THE GEOLOGIC STRUCTURE AND THE POTENTIALITIES OF THE BAZHENOV CHRYSOTILE-ASBESTOS DEPOSIT]: Inform. byul. Ural'sk. geol. upr. i Soveta nauch.-tekhn. gorn. o-va, no. 1 (13).

139. Taldykina, K.S., STADII MINERALOOBRAZOVANIYA V POLIMETALLICHESKOM MESTOROZHDENII SAVINSKOYE NO. 5 [STAGES OF MINERALIZATION AT THE SAVINSKOYE NO. 5 POLYMETALLIC DEPOSIT]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

140. Tarkhaneyev, B.F., NOVOYE YELOVSKOYE MESTOROZHDENIYE NIZHNEKARBONOVYKH KAMENNYKH UGLEY NA VOSTOCHNOM SKLONE SREDNEGO URALA [NOVOYE YELOVSKOYE — A NEW DEPOSIT OF LOWER CARBONIFEROUS COAL ON THE EASTERN SLOPE OF THE MIDDLE URALS]: Inform. byul. Ural'sk. geol. upr. i Soveta nauchn.-tekhn. gorn. o-va, no. 1 (13).

141. Trofimuk, A.A., OTKRYTIYE URALO-VOLZHSKOY NEFTENOSNOY OBLASTI-NAUCHNYY PODVIG I.M. GUBKINA [DISCOVERY OF THE URAL-VOLGA PETROLIFEROUS PROVINCE — I.M. GUBKIN'S SCIENTIFIC ACHIEVEMENT]: Geol. nefti i gaza, no. 4.

142. Shmakin, B.M., FLOGOPITONOSNOST' DIOPSIDOVYKH POROD KURANAKHSKIKH MESTOROZHDENIY (YUZHNAYA YAKUTIYA) [PHLOGOPITE CONTENT IN THE DIOPSIDE ROCKS OF THE KURANAKH DEPOSITS (SOUTHERN YAKUTIYA)]: Izv. vysh. uchebn. zaved., ser. geol.

i razvedki, no. 1.

143. Shcheglov, A.D., GLAVNYYE OSOBENNOSTI METALLOGENII YUZHNOY CHASTI ZAPADNOGO ZABAYKAL'YA [PRINCIPAL CHARACTERISTICS OF METALLOGENY IN THE SOUTHERN PART OF WESTERN TRANSBAIKALIYA]: Doklady, Akademiya Nauk SSSR, t. 125, no. 4.

HYDROGEOLOGY, ENGINEERING GEOLOGY

144. Vladimirov, A.G., DIFFERENTSIAL'NYY BALANS GRUNTOVYKH VOD [DIFFERENTIAL BALANCE OF GROUND WATERS]: Sov. geol., no. 2.

145. Germanov, A.I., G.A. Volkov, A.K. Lisitsin and V.S. Serebrennikov, OPYT IZUCHENIYA OKISITEL'NO-VOSSTANOVITEL'NOGO POTENTSIALA PODZEMNYKH VOD [A STUDY OF THE OXIDATION-REDUCTION POTENTIAL OF GROUND WATERS]: Geokhimiya, no. 3.

146. Zamanov, Kh.D. and I.A. Kotlyarskiy, OB OZERE GEYGEL' V BASSEYNE REKI SHAMKHORCHAY [LAKE GEYGEL' IN THE BASIN OF THE SHAMKHORCHAY RIVER]: Doklady, Akademiya Nauk Azerb.S.S.R., t. 15, no. 2.

147. Kaspirova, M.A., K VOPROSU O GIDROGEOLOGII PRIDARVAZ'YA [HYDROGEOLOGICAL PROBLEMS OF THE DARVAZ REGION]: Vestn. LGU, no. 6, ser. geol. i geogr., vyp. 1.

148. Lykoshin, A.G., OSNOVNYYE VOPROSY I METODY INZHENERNO-GEOLOGICHESKIKH ISSLEDOVANIY KARSTA V SVYAZI S GIDROENERGETICHESKIM STROITEL'STVOM [MAIN PROBLEMS AND METHODS OF ENGINEERING AND GEOLOGICAL INVESTIGATIONS OF KARST FOR HYDROELECTRIC CONSTRUCTION]: Izv. vyssh. uchebn. zaved., ser. geol., i razvedki, no. 1.

149. Moldavskiy, B.S., O GIDROKHIMICHESKOY ZONAL'NOSTI PLASTOVYKH VOD KARADAGA [HYDROCHEMICAL ZONATION OF THE GROUND WATER IN THE KARADAG RANGE]: Izv. vyssh. uchebn. zaved., ser. neft. i gaz, no. 2.

150. Ryabchenkov, A.S., O PRINTSIPAKH GIDROGEOLOGICHESKOY STRATIFIKATSII [THE PRINCIPLES OF HYDROGEOLOGIC STRATIFICATION]: Sov, geol. no. 3.

151. Yashchenko, Z.G., OPYT PRIMENENIYA ELEKTRORAZVEDKI DLYA ISSLEDOVANIYA PROYAVLENIY KARSTA V DOLINAKH REK ANGARY I ZAPADNOY DVINY [AN EXPERIMENT IN ELECTRICAL PROSPECTING FOR KARST PHENOMENA IN THE VALLEYS OF THE ANGARA AND WESTERN DVINA RIVERS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedki, no. 1.

B. Papers in "Materialy," "Trudy," "Uchenyye Zapiski," and "Sborniki"

1. Geokhimiya Redkikh Elementov v Svyazi s Problemoy Petrogenezisa [Geochemistry of rare elements in connection with the problem of petrogenesis]: Moscow, 1959, 167 p. Contents: Borisenok, L.F., and V.V. Shcherbina, Regularities of distribution of scandium and vanadium in igneous rocks and their minerals. Tugarinov, A.I. and E.Ye. Vaynshteyn, Regularities of distribution of rare earths, zirconium and hafnium in igneous rocks. Gerasimovskiy, V.I. and Ye.B. Znamenskiy, Regularities of distribution of niobium and tantalum in igneous rocks. Beus, A.A., Regularities of distribution of beryllium in igneous rocks. Ahrens, L.H., Possible significance of the rare alkali metals for understanding the origin of igneous rocks. Tauson, L.V. and Z.V. Studenikova, Regularities of distribution of lead, zinc and molybdenum in igneous rocks. Ingerson, E., Composition of rare earths in two Brazilian pegmatites. Sadetskiy-Kardosh, Ye., The influence of the enclosing rocks on the distribution of elements in magmatites. Belov, N.V., Crystal chemistry of the main process of crystallization of magma. Koptev-Dvornikov, V.S., M.G. Rub, L.V. Dmitriyev and Ye.V. Negrey, Pattern of formation of granitic intrusions. Vinogradov, A.P., Isotope ratios in igneous rocks.

2. Materialy VSEGEI, nov. ser., vyp. 24, obshch. ser., L., 1959. 184 p. Contents: Kornutova, Ye.I., Aerial surveys in the geological and geomorphological investigations in the Vilyuy River basin. Nekrasova, O.I. and N. Ye. Chernyshev, New data on lower and middle Cambrian Stratigraphy of the southeastern margin of the Siberian platform. Kolyun, M.N., Stratigraphic and lithological description of the Cambrian Verkhnolensk formation on the middle and upper course of the Lena River. Tazikhin, N.N., Jurassic deposits in the basin of the Bol'shaya Botuobiya River. Plotnikova, M.I., N.P. Il'yukhina and

V.N. Umanets, The problem of the "watershed gravels" of the Markha River basin. Masaytis, V.L., Fracture intrusions of the Vilyuy-Markha flexure. Tuganova, Ye.V., A differentiated basaltic intrusion in the Kholomolakh River. Baskov, Ye.A., Ground water of the Yakutian artesian basin and certain possibilities of their utilization. Baskov, Ye.A. and Ye.I. Kornutova, Karst in southern Yakutiya. Mironyuk, Ye.P., Geomorphology of the eastern margins of the Yablonovoy and Udokan ranges.

Sbornik Materialov po Geologii Tsvetnykh, Redkikh i Blagorodnykh Metallov [Collection of papers on the geology of nonferrous, rare and precious metals]: vyp. 4, M., 1959, 176 p. Contents: Prosnyakov, M.P., Methods of prospecting for tabular lead-zinc deposits. Fedorchuk, V.P. and others, Methods of prospecting and exploration of concealed ore bodies within the boundaries of exploited bedded deposit of mercury and antimony. Bozhinskiy, A.P., Certain methods of prospecting for placers. Buynov, A.A., On the simplification of spectrographic-metallometric assaying in exploration for mercury. Volarovich, G.P., Distribution and conditions of concentration of lead-zinc mineralization within the boundaries of the main geotektonic units of Primo'ye. Sher, S.D., Basic dike rocks in the basin of the Bodaybo River and their relation to quartz veins. Timofeyevskiy, D.A., On the facies of the small intrusives and the role of gas explosion pipes of the Darasun mineralized area in eastern Transbaikaliya. Osetrov, O.A., Some trace elements in the ores of the Verkhnearshinsk pyrite-polymetallic deposit in the southern Urals. Stepanov, G.A., The abundance of native gold in the ores of the deeper zones of the Berezovka deposit in the Urals. Shabalovskiy, A.Ye., Rutile-bearing quartzites in the upper waters of the Kutim River in the northern Urals. Novk-Kachan, V.P., Methods of supplying placers with water.

Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Galurgii [Work of the All-Union Research Institute of Halurgy]: vyp. 35, 1., 1959. Contents: Vakhrameyeva, V.A., Comparative description of rocks of sulfate deposits (Kara-Bogaz and the intermountain basin of Tien Shan). Dzens-Litovskiy, A.I., M.Yu. Garkavi, G.A. Vasil'yev and L.V. Yelovskaya, Bottom sediments and buried brine of Kara Bogaz as a new source of sulfate. Korenevskiy, S.M., O.P. Gorkun, A.V. Roller and R.E. Shleymovich, Possible potash deposits in some new areas of the pre-Carpathian downwarp. Korenevskiy, S.M., Geological environment of sodium sulfate deposition in the Ciscarpathian region. Horkun, O.P., The stratigraphic position and lithology of potash lenses in the Verkhnevorotyshchensk formation of thė Stebinsk region. Korenevskiy, S.M., Geological description of the salt structures of the Verkhne-Tissensk basin. Alfer'yev, G.P. and L.N. Kudrin, On correlation of sections of the Tyachevsk formation in the Verkhne-Tissensk basin. Dzens-Litovskiy, A.I., I.K. Smeshlivyy and V.A. Shurygin, Mirabilite salt pans of the Chul'adyr salt deposit. Khod'kov, A.Ye. and I.N. Shevchenko, Secondary rocks of the Slavinskoye rock salt and their textures and structures. Korenevskiy, S.M., Gas in the salt and the underlying rocks of the Kalush-Golynsk region. Nesmelova, Z.N., Gases in the potassium salts of the Bereznikovo mine. Fiveg, M.P., Texture of the lower rock salt of the Verkhnekamsk deposit. Vakhrameyeva, V.A., Jointing in the rocks of the carnallite zone in the Verkhnekamsk deposit. Korobov, S.S., New data on the geologic structure of the Chapchachi region. Yarzhemskiy, Ya.Ya., A brief mineralogical and petrographic description of the salt-bearing strata in the Kaliningrad borehole 1-P. Lebedev, V.I., Reasons for the absence of potassium salts in the sediments of continental lakes. Zakharov, V.F., A.Ye. Khod'kov and I.N. Kovaleva, Brines overlying the salt in the Ciscarpathian region. Gayun, K.G., On the origin of the ground waters in the region of the Gruskavets resort. Zakharov, V.F., and P.S. Bobko, Hydrogeology and geomorphological features of the Kalush basin in Ciscarpathia. Bobko, P.S., Solution of the problem of brine extraction at the Mirovsk deposit of rock salt. Khod'kov, A.Ye., A.I. Belolikov, M.S. Isakova and K.G. Khidarova, Causes of salinity of ground waters in the catchment area of the Verkhnekamsk deposit. Khod'kov, A.Ye., Artificial industrial karst and its hydrogeologic significance. Khod'kov, A.Ye., Geological role of subsurface leaching of salt beds. Khod'kov, A.Ye., Ground waters derived from the sediments and the geochemical role of their migration. Khod'kov, A. Ye., The role of precipitation from ground waters in the formation of potash deposits of Ciscarpathia.

5. Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Prirodnykh Gazov

[Transactions of the All-Union Natural Gas Research Institute]: vyp. 7 (15). L., 1959, 146 p. Contents: Pashkevich, Ye.I., P.M. Pistrak and N.A. Samborskiy, Stratigraphy of Devonian deposits of the marginal zone of the Dnepr-Donets basin. Shalya, A.A. and G.B. Sal'man, Neocomian deposits of the southwestern and steppe Crimea in the light of new data. Kotel'nikov, D.D., L.A. Kosheleva, and O.V. Snegireva, Composition and origin of the clay minerals in the middle and upper Jurassic sediments of the Sudak-Koktebel' folded zone of eastern Crimea. Panov, D.I. and Yu.G. Leonov, Main problems of lower and middle Jurassic stratigraphy in the Kuban'-Baksan interfluve. Loginova, G.A., Callovian deposits of the western and central parts of the northern slope of the Caucasus. Kozyar, L.A. and V.A. Zagoruyko, The results of palynological analysis of the section from the Bulganak borehole no. 1 (Crimea). Babay, V.S., Lithology and correlation of the Khadum formation on the basis of certain section in the Stavropol' region. Khanin, A.A. and Z.V. Fedorova, Collector properties of some of the carboniferous deposits of the Volga upland.

6. Trudy Vsesoyznogo Neftegazovogo Nauchno-Issledovayel'skogo Instituta [Transactions of the All-Union Oil and Gas Research Institute]: vyp. 20. M., 1959. Contents: Gryaznov, N.K., Certain stages in the history of formation of structures and the conditions of petroleum accumulation in the Devonian of the Romashkinskiy and adjacent regions. Mikhaylovskiy, N.K. and Ye.I. Semin, The boundary between D_I and D_{II} beds at the Tuymasinskii deposit. Petrovskaya, A.N., The problem of detailed correlation of sections of productive continental deposits. Volovikovskaya, Ye.P., An experiment in correlation of upper Zhivetian and Pashiyskian deposits by the variations in vanadium concentration as determined by spectrography. Dolina, L.P., Determination of porosity, permeability and concentration of petroleum from geophysical data and an attempt to use the results in estimating petroleum reserves. Stasenkov, V.V., Investigation of the coefficient of petroleum yield from thin alternating beds on the basis of geological and production data. Voynov, V.V. and Ye.I. Semin, On the methods of drawing structure maps and oil content contours in the case of a disrupted bed. Rodionova, K.F., N.V. Kiriyenkova, K.M. Makarochkina and Z.S. Kotosheva, The nature of organic matter in the Devonian productive beds penetrated by borehole 44 at the Shkapovskoye field. Rodionova, K.F., Ye.M. Mochalova and A.I. Volodchenkova, Iron and carbonate minerals in the rocks of the productive Devonian strata as indicators of the conditions of their deposition. Chizhova, V.A., The use of ostracods for the subdivision of the productive lower Carboniferous beds of the Saratov-Stalingrad region along the Volga.

7. Trudy Instituta Geologii Rudnykh Mestorozhdeniy, Petrografii, Mineralogii i Geokhimii [Transactions of the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry]: vyp. 31, M., 1959, 119 p. Contents: Petrov, V.P. and Yu.K. Andreyev, Mineralogy of asbestos and the position of the amphibole asbestos of the U.S.S.R. in the general classification. Yermeyev, V.P., B.Ya. Merenkov, V.P. Petrov and L.A. Sokolov, Chrysotile asbestos deposits as a form of contact action of granitoids on ultrabasic rocks. Merenkov, B.Ya., K.I. Tolstikhina and A.L. Aleksandrov, The importance of electron microscope study of chrysotile asbestos and serpophite in solving the problem of their origin. Merenkov, B.Ya., "Fibrous" vein magnetite from the Bazhenovo chrysotile asbestos deposit. Merenkov, B.Ya., Tolstikhina, K.I. and I.V. Shumikhina, Dehydration of chrysotile and serpophite. Yeremeyev, V.P., Petrography and origin of chrysotile asbestos of the Atovrak deposit. Andreyev, Yu.K. and V.N. Godovikov, Conditions of alkalic hornblende mineralization in the marlstones of the Dzheskazgan basin.